Methodologies for Evaluating
Congestion Mitigation and Air Quality Improvement Projects

Maricopa Association of Governments

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Table of Contents

INTRODUCTION

The purpose of the Congestion Mitigation and Air Quality Improvement (CMAQ) Program is to provide federal funding for projects and programs designed to assist nonattainment and maintenance areas in complying with the National Ambient Air Quality Standards. The most recent federal guidance for the CMAQ Program, effective April 28, 1999, indicates that Metropolitan Planning Organizations (MPOs) need to develop procedures for assessing emission reduction benefits for proposed CMAQ projects. In accordance with this guidance, the Maricopa Association of Governments (MAG) has developed methodologies for quantifying emission reductions and cost-effectiveness for CMAQ projects. The CMAQ methodologies were previously documented in the MAG Methodologies for Evaluating Congestion Mitigation and Air Quality Improvement Projects, April 16, 2004. The revised CMAQ methodologies in this document are based on input received at the CMAQ workshop conducted by MAG on June 28, 2005.

Previous Revisions to the CMAQ Methodologies

In 2002, MAG contracted with Sierra Research to review CMAQ methodologies and identify the most promising project evaluation techniques used by ten MPOs in the western U.S, including MAG. On April 29, 2002, MAG conducted a half-day workshop describing the CMAQ methodologies in use by these ten MPOs and the findings and recommendations of the Sierra Research study. In general, Sierra concluded that "the methods established by MAG for computing the cost-effectiveness of proposed CMAQ projects are easily the most sophisticated encountered in the review of western communities."

Since Sierra Research concluded that MAG had the most sophisticated methodologies, major changes were not required. However, many of the formulas were updated to reflect the recommendations in the Sierra Research report, Review of Methodologies for Evaluating CMAQ Projects, May 30, 2002. All but one of the Sierra Research recommendations below have been incorporated into this latest version of the CMAQ methodologies.

Recommendation #1: The analysis methodologies should be revised to calculate emission reductions only for the months of the year in which violations typically occur:

- *Three winter months for CO*[1]*;*
- *Five summer months for ozone precursors (TOG and NOx)*[2]*; and*
- *Twelve months for PM-10*[3]*.*

This recommendation has been incorporated into the 2004 and 2005 MAG CMAQ methodologies.

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[1]CO = carbon monoxide

[2]TOG = total organic gases; NOx = oxides of nitrogen

[3]PM-10 = particulate matter less than or equal to 10 microns in diameter.

The equations were updated to include seasonal factors for all project types. However, the TOG and NOx emission reductions are assumed to occur during a six month period, rather than the recommended five, because high temperatures contributing to elevated ozone concentrations are typically recorded for a six-month period (April 15 through October 15) in the MAG region.

Recommendation #2: Reductions in ozone precursor emissions, both TOG and NOx, should be calculated for all candidate CMAQ projects.

This recommendation has been implemented in the 2004 and 2005 MAG CMAQ methodologies. The draft one-hour ozone maintenance plan for Maricopa County established conformity budgets for TOG and NOx. Therefore, the CMAQ methodologies also recognize the benefit of reductions in both TOG and NOx emissions.

Recommendation #3: The annual values of both cost and weighted emission reductions should be discounted to the present value and used to compute cost-effectiveness values. To minimize the analysis burden, consideration should be given to establishing generic categories of lifetime project benefits (e.g., increasing, constant, decreasing, etc.)

This recommendation is the only one that has not been implemented. The 2001 Transportation Research Board (TRB) report by J. Richard Kuzmyak, "Cost-Effectiveness of Congestion Mitigation and Air Quality (CMAQ) Strategies" concluded that CMAQ methodologies should discount emission reduction benefits, as well as costs. In the 2005 CMAQ methodologies, the cost recovery factor has been reduced from five to three percent, which reduces the cost factor's influence on cost-effectiveness. For test purposes, the CMAQ equations were applied with a benefit discount factor of three percent for all example projects with a life expectancy of more than three years. The cost-effectiveness scores calculated using the three percent benefit discount factors had little impact on the rank order of example projects. In addition, assigning projects to the appropriate category of lifetime benefits (i.e. increasing, constant, and decreasing) is a difficult and highly subjective task. For these reasons, benefit discount factors are not being applied at this time.

Recommendation #4: A process should be established for prioritizing the directly emitted and precursor emission reductions for the following criteria pollutants:

- *CO*
- *1-hour ozone*
- *8-hour ozone*
- *PM-10*
- *PM-2.5*

The results of the process should be used to weight the seasonal emission reduction estimates computed for each candidate CMAQ project.

This recommendation has been implemented in the 2005 MAG CMAQ methodologies. The prioritization recommended by Sierra Research has been accomplished by applying weighting factors to the pollutants of greatest concern to the region. At the CMAQ workshop held on June 28, 2005, participants provided input concerning the priorities that should be assigned to the criteria pollutants. Participants agreed that projects reducing PM-10 should have the highest priority for CMAQ funding, because the PM-10 standards have not been met. They favored assigning lower priorities to TOG and NOx than PM-10, because the one-hour ozone standard has not been violated since 1996. In addition, eight-hour ozone concentrations are also declining, with only one monitor violating the eight-hour standard in 2004. It was also suggested that CO emission reduction benefits be eliminated from the formulas, because the federal standards for CO have not been violated since 1996 and monitored values are now well below the standards.

To reflect comments received at the workshop, new priority weights were assigned. The 2005 light duty vehicle emission rates for TOG and NOx were set equal to the PM-10 rate of 0.78 grams per vehicle mile of travel.[4] The weights for TOG and NOx were then reduced by 50 percent and the weight for CO was set to zero. PM-2.5 is not included in the MAG CMAQ methodologies, because the Phoenix-Mesa Metropolitan Statistical Area was designated a PM-2.5 attainment area in September 2004.

The resultant weighting factors will be used in calculating cost-effectiveness for projects requesting CMAQ funding. The priority weights shown below will be applied to the seasonally weighted emission reductions (i.e., TOG and NOx are divided by two to reflect the six-month ozone season). The cost-effectiveness calculations for the example projects in this document have been updated with these new priority weights. Their use will result in cost-effectiveness scores that differ significantly from those calculated using previous versions of the MAG CMAQ methodologies.

Pollutant	2005 Light Duty Vehicle Emission Rates	Priority Weight	Weighted Emission Rates
CO	11.20 grams/mile	0.00	0.00 grams/mile
TOG	1.12 grams/mile	0.37	0.41 grams/mile
NOx	0.93 grams/mile	0.44	0.41 grams/mile
PM-10	0.82 grams/mile	1.00	0.82 grams/mile

Recommendation #5: Emission factors used in the analysis of candidate CMAQ projects should be consistent with those used in the applicable SIP. Generally speaking, MOBILE6 values should not be used until the applicable SIPs have been updated. In selected cases where the available emission factors fail to account for significant changes in certification standards, it may be necessary to obtain them from MOBILE6.

This recommendation has been adopted in both the 2004 and 2005 CMAQ methodologies. The EPA MOBILE6 model was used to generate the on-road mobile source TOG and NOx emissions in the EPA-approved one-hour ozone maintenance plan. The EPA PART5 model was used to estimate paved and unpaved road emissions of PM-10 in the Serious Area PM-10 Plan. The latest version

[4]The 2005 light duty vehicle emission rates were derived from MOBILE6.2. Reentrained PM-10 from paved roads was derived from PART5.

of these models will be used to estimate emissions and cost-effectiveness in the CMAQ methodologies.

CMAQ Project Review Process

Each year MAG programs available CMAQ funds. As part of the programming process, jurisdictions are requested through the MAG Management Committee, Transportation Review Committee, and MAG modal committees, to submit requests for federally funded projects. Guidance on projects eligible for CMAQ funding is provided in Section IX of the Transportation Improvement Program Guidance reports. After the receipt of project requests, MAG evaluates CMAQ projects for possible inclusion in the Transportation Improvement Program. The MAG modal committees are furnished with the CMAQ assessment, along with the Congestion Management System rating system score, for project evaluation purposes. Recommendations from the MAG modal committees are forwarded to the Transportation Review Committee for programming consideration.

The CMAQ project assessment may be in the form of a quantitative analysis resulting from the methodologies or a qualitative evaluation. CMAQ guidance allows a qualitative evaluation to be made when a quantitative analysis is not possible, although every effort will be made to quantify the emissions reduction impact of each project. Qualitative assessments may be based on a reasonable review of how a project or program will decrease emissions. Committed transportation control measures identified in the air quality plans receive priority in CMAQ project programming.

The CMAQ methodologies provide options for local input, while striving to keep the overall data requirements from being overly complex and burdensome. In general, agencies submitting CMAQ projects may provide local data to replace default values in any of the methodologies, as long as there is supporting written documentation. The values to be substituted and the supporting documentation (i.e., traffic engineering modeling; city-specific survey data) must accompany the request for CMAQ funding.

The methodologies included in this report were developed in response to federal guidance (FHWA, 2000) requiring the quantification of emission reductions for proposed CMAQ projects, whenever possible. Other potential project benefits such as human health, safety, land use, and congestion mitigation impacts are not addressed. It is also important to note that emission reductions and cost-effectiveness are not the only factors considered in evaluating and selecting candidates for CMAQ funding.

Overview of Key Assumptions

The methodologies for quantifying the emission reductions and cost-effectiveness of typical CMAQ projects are described below. In general, the methodologies involve the estimation of (1) emission reductions in kilograms per day, which are the sum of reductions in TOG, NOx, and PM-10; and (2) the cost-effectiveness of each project in dollars per metric ton of emissions reduced per year.

Because the CMAQ methodology uses the latest EPA emissions models and regional planning assumptions, the emission reductions may not be consistent with previous CMAQ analyses or air quality plans that used earlier EPA models and assumptions. Some projects do not reduce PM-10 emissions and only CO, TOG, and NOx emissions are calculated. In other cases, only PM-10 emissions are reduced. If a proposed project combines two project types (i.e., paving a dirt road and adding a bicycle lane), the combined impact of the two portions of the project is included in the total emission reduction.

The EPA MOBILE6 emissions model will be run to estimate CO, TOG, NOx, and PM-10 emission factors for the implementation year of the project, assuming that the project is implemented in the CMAQ funding year. The MOBILE6 emission factors will be based on the latest vehicle registrations and diesel split factors. The PM-10 emissions output by MOBILE6 include tailpipe exhaust, tire wear and brake wear emissions. The average speed of area-wide traffic is assumed to be 30 miles per hour, unless specified otherwise in the methodologies.

PM-10 emission rates for paved and unpaved roads are derived from the EPA PART5 model runs for the Serious Area PM-10 Plan (MAG, 2000a). In the CMAQ methodologies, the emission rates for reentrainment of PM-10 on paved roads are as follows: freeways - 0.16 grams per mile; low traffic arterials (less than 10,000 vehicles per day) - 1.59 grams per mile; average for all arterials - 1.10 grams per mile; and average for all road types - 0.79 grams per mile. The unpaved road emission rate used in the methodology for paving unpaved roads is 573.91 grams per mile.

Since there have been no violations of the CO standard since 1996 and monitored values continue to decline, CO emission reductions are not utilized in estimating daily emission reductions or cost-effectiveness for projects requesting CMAQ funding. The priority weight on CO has been set to zero in the CMAQ equations. However, daily CO emission reductions will continue to be reported to FHWA for projects in the CMAQ annual report. For this report, CO emission reductions will be calculated for the range of temperatures on the winter episode day in the EPA-approved carbon monoxide maintenance plan (MAG, 2003).

TOG and NOx emissions will be calculated for the range of temperatures on the summer episode day in the EPA-approved one-hour ozone maintenance plan (MAG, 2004). In the calculation of total emissions and cost-effectiveness for projects requesting CMAQ funding, TOG and NOx reductions will be divided by a seasonal factor of two to account for the six-month ozone season.

Temperature is not used in estimating PM-10 emissions, and no seasonal factor is applied, because exceedances of the daily PM-10 standard can occur at any time of year. Because of the seasonal and priority weighting assumptions discussed above, total emission reductions of TOG, NOx, and PM-10 for CMAQ projects do not represent an average day during the year.

In the CMAQ methodologies, the cost-effectiveness of a project is calculated by dividing the annualized CMAQ cost by the annual emission reduction. The annual emission reduction is obtained by converting the total weighted reduction in TOG, NOx and PM-10 emissions in kilograms per day to metric tons per year. The CMAQ cost is amortized over the expected project life using a three percent discount rate, which represents the opportunity cost of using public dollars to fund a project, versus investing the same funds in a certificate of deposit earning three percent per year over the life of the project. The general approach for calculating cost-effectiveness and the discount rate are consistent with the California Air Resources Board (CARB), Methods to Find the Cost-Effectiveness of Funding Air Quality Projects, May 2005.

The remainder of this document describes the methodologies and assumptions to estimate emission reductions and cost-effectiveness for typical CMAQ projects. The description of the methodology for each project type is divided into three sections. The first section describes the modeling methodology, assumptions, and defaults. The second lists the data that are requested from the entity proposing the project. If any of the required data are not provided, default assumptions are substituted. The third section provides the formulas used in the analyses. Data from the first and second sections are input to the formulas to estimate the emission reduction and cost-effectiveness of a proposed project. At least one example calculation is provided for each project type. The examples represent generic CMAQ projects, provided to demonstrate how the methodology will be applied. The emission reductions and cost-effectiveness calculated for actual CMAQ projects will be dependent upon local inputs and may vary substantially from the examples.

This document describes methodologies for the following project types, in alphabetical order: Bicycle and Pedestrian Facilities, Bus and Light Rail Projects, Diesel Retrofits, Freight Projects, High Occupancy Vehicle (HOV) Facilities, Intersection Improvements (including Roundabouts), Ozone Education Program, Park and Ride Facilities, Paving Projects, PM-10 Certified Street Sweepers, Rideshare Programs, Telework Program, Traffic Flow Improvements, Trip Reduction Program, and Vanpool Vehicles.

These represent the most common CMAQ project types in the MAG region. CMAQ-eligible projects that do not fall into one of these categories will also be quantified, if feasible, on a case-by-case basis. If CMAQ funding for one phase (i.e. planning or design) of an eligible project is requested, the emission reduction benefit will be calculated for the first year that the project is completed. If additional CMAQ funds have been or will be requested to complete a project (i.e., light rail), the requesting entity will be asked to estimate the total CMAQ funds to be used in calculating the cost-effectiveness for the project.

Application of Methodologies

The CMAQ methodologies calculate cost-effectiveness, a measure that is used in prioritizing projects that are candidates for future CMAQ funds. The methodologies are also used to quantify daily emission reductions for annual CMAQ reports submitted to FHWA. If emission reduction credit for a CMAQ-funded project in the Transportation Improvement Program has not been taken in a State Implementation Plan (SIP), the benefits of the project may also be used in transportation conformity. Since the annual CMAQ report and conformity analyses require emission reductions by individual pollutant, the priority weights (*w1, w2, w3, w4*) and seasonality factors (i.e., dividing VOC and NOx by two) are not used in these applications.

BICYCLE AND PEDESTRIAN FACILITIES

"Encouragement of Bicycle Travel" and "Development of Bicycle Travel Facilities" are committed control measures in the Serious Area CO Plan (MAG, 2001) and Serious Area PM-10 Plan (MAG, 2000a). Bicycle facilities have the potential to reduce commute and other non-recreational trips. Bicycle paths are facilities which are physically separated from motor vehicle traffic. Bicycle lanes are striped for preferential or exclusive use of bicycles. CO, TOG, NOx, and PM-10 emission reductions occur when bicycle trips replace single occupant vehicle trips.

"Encouragement of Pedestrian Travel" is also a committed control measure in the MAG Serious Area CO and PM-10 Plans. Pedestrian facilities provide or improve pedestrian access. Emissions are reduced when vehicle trips are replaced by walking.

The CO, TOG, NOx, and PM-10 emission factors are calculated for the implementation year of the project. The project life for bicycle and pedestrian paths and bicycle lanes on roads or shoulders is twenty years; fifty years, for overpasses and underpasses. The average weekday traffic (***ADT***) estimates for the adjacent or nearest parallel arterial must be provided by the entity requesting CMAQ funding for the project.

MOBILE6 will be run assuming a speed of 30 miles per hour to estimate CO, TOG, NOx, and PM-10 emission factors for light duty vehicles. Since it is assumed that bicycle/pedestrian trips replace vehicle trips that are four miles or less, the cold start emission factor will be used for all vehicle trips replaced by bicycle/pedestrian trips ($\boldsymbol{CEF_{CO}}$, $\boldsymbol{CEF_{TOG}}$, $\boldsymbol{CEF_{NOx}}$, $\boldsymbol{CEF_{PM}}$). Evaporative emissions from the hot engine at the end of each trip will also be estimated for TOG ($\boldsymbol{HEF_{TOG}}$).

The number of vehicle trips replaced by bicycle or pedestrian trips will be estimated based on the average weekday traffic on the adjacent or nearest parallel arterial to the bicycle/pedestrian path. The ADT on the road will be converted to annual average daily traffic (AADT) by multiplying by 0.91. The vehicle trips reduced will be estimated using the adjustment factors from Table 3. The adjustment factors are dependent upon the length of the bicycle/pedestrian project and the AADT on the road parallel to the bicycle/pedestrian project. Given the relative importance of bridges and underpasses that connect bicycle/pedestrian paths, the adjustment factor used for bridges and underpasses will be based on the sum of the lengths of the two paths connected.

Estimates of the VMT reduced are based on the average number of vehicle trips reduced, multiplied by average trip lengths. Consistent with assumptions in MAG transportation modeling concerning pedestrian trips to transit centers, a pedestrian trip length of one-half mile will be assumed. Based on data in Bicycle Demand and Benefit Model (Alta Transportation Consulting, April 2000) an average bicycle trip length of four miles will be assumed. For multi-use paths, it will be assumed that half of the trips are bicycle and half are pedestrian. Therefore, an average trip length of 2.25 miles will be assumed for multi-use paths.

The usefulness of a bicycle/pedestrian path is also dependent upon its location. Usage estimates for bicycle/pedestrian paths will take into consideration the number of activity centers near the proposed bicycle/pedestrian path. The credit for activity centers along a bicycle/pedestrian path is shown in Table 4.

Table 3. Adjustment Factors[5]

ANNUAL AVERAGE DAILY TRAFFIC (AADT)	LENGTH OF PROJECT (one direction)	**ADJUSTMENT FACTOR (*A*)**
AADT ≤ 12,000 vehicles per day	≤ 1 mile	0.0019
	> 1 mile and ≤ 2 miles	0.0029
	> 2 miles	0.0038
12,000 < AADT≤ 24,000 vehicles per day	≤ 1 mile	0.0014
	> 1 mile and ≤ 2 miles	0.0020
	> 2 miles	0.0027
AADT > 24,000 vehicles per day	≤ 1 mile	0.0010
	> 1 mile and ≤ 2 miles	0.0014
	> 2 miles	0.0019

Table 4. Activity Center Credits[6]

Examples of Activity Centers: bank, church, hospital or HMO, park and ride, office park, post office, public library, shopping area or grocery store, schools, university or junior college.

Number of activity centers	**Credit (C)**	
	Within ½ mile	Within ¼ mile
at least three	0.0005	0.001
more than three but less than seven	0.001	0.002
seven or more	0.0015	0.003

The formulas below are used to calculate the annual emission reductions and cost-effectiveness of bicycle and pedestrian facilities.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*.**

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[5]Data adapted from CARB, Methods to Find the Cost-Effectiveness of Funding Air Quality Projects, May 2005.

[6]Ibid.

- Average weekday traffic (***ADT***) on the nearest parallel arterial.
- Number of activity centers (i.e. bank, church, hospital, HMO, light rail station, park and ride lot, office park, post office, public library, shopping area, grocery store, university or junior college) within ¼ mile and ½ mile of the bicycle/pedestrian project.
- Length of bicycle/pedestrian path (for a bridge/underpass; the combined length of the paths connected by the bridge/underpass).

Formulas:

$$\textit{Trips Reduced } (\boldsymbol{TR}) = \boldsymbol{ADT} * 0.91 * (\boldsymbol{A} + \boldsymbol{C})$$

where: ***A*** = the adjustment factor from Table 3
C = the activity center credit from Table 4
ADT = the average weekday traffic on the adjacent or nearest parallel arterial
0.91 = factor to convert average weekday traffic to annual average daily traffic
ADT * 0.91 = the annual average daily traffic (**AADT**) on the adjacent or nearest parallel arterial

$$\textit{VMT Reduced } (\boldsymbol{VR}) = \boldsymbol{ATR} * \textbf{\textit{trip length}}$$

where: ***trip length*** = the length of a bicycle trip is assumed to be 4.0 miles and the length of a pedestrian trip is assumed to be 0.5 miles. For a multi-use path, it is assumed that the average trip length is 2.25 miles

$$\textit{Daily Emissions Reduction} = [(\boldsymbol{TR} * \frac{w2 * HEF_{TOG}}{2}) +$$

$$(\boldsymbol{VR} * (\frac{w1 * CEF_{CO}}{4} + \frac{w2 * CEF_{TOG}}{2} + \frac{w3 * CEF_{NOx}}{2} + (w4 * (CEF_{PM} + PEF))))] * \frac{1}{1000} = \frac{kilograms}{day}$$

where: $\boldsymbol{HEF_{TOG}}$ = the hot soak light duty vehicle trip end emission factor for TOG
CEF = the cold start light duty vehicle emission factor for each pollutant
PEF = the paved road PM-10 emission factor for arterials
w1-w4= weighting factors for CO, TOG, NOx, and PM-10, respectively

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: i = discount rate of 3 percent
$life$ = effectiveness period of 20 years for bicycle and pedestrian paths; 20 years for a bicycle lane on a road or shoulder; and 50 years for an overpass or underpass.

$$Cost\text{-}Effectiveness = \frac{\mathbf{CRF} * \mathbf{CMAQ\ Cost} * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Bicycle and Pedestrian Facilities **EXAMPLE**

A city proposes to pave an unpaved shoulder and create a 1.5 mile long bike lane in 2005 at a total cost of $650,000, where $65,000 will be paid with local funds. The bike lane will be adjacent to an arterial with average weekday traffic (**ADT**) of 18,000 vehicles per day. There are three activity centers (a grocery store, a library, and a park and ride) less than one-quarter mile from the path. There are four additional activity centers (two office parks, a church, and a post-office) between one-quarter and one-half mile from the path for a total of seven activity centers within one-half mile.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $585,000.
- Project length (***miles***) = 1.5 miles.
- Average weekday traffic (***ADT***) on adjacent arterial = 18,000.
- Activity centers within ¼ mile = 3 OR activity centers within ½ mile = 7.

Calculations:

The primary Adjustment Factor (**A**) is calculated from Table 3. Since the **ADT** is 18,000, the annual average daily traffic (**AADT**) is 16,380 (0.91 x 18,000). From Table 3, the adjustment factor for a path adjacent to a roadway with between 12,000 and 24,000 AADT and between one and two miles in length is 0.0020. The Activity Center Credit (**C**) is calculated from Table 4. There are two choices of activity center credit for this project, since there are three activity centers within one-quarter mile (0.001) and seven centers within one-half mile (0.0015). The higher value, 0.0015, is chosen. Additional credit will also be given to the project for reducing PM-10 by paving an unpaved shoulder. The emission reduction credit for paving an unpaved shoulder is 0.80 grams per mile.

$$Trips\ Reduced\ (\boldsymbol{TR}) = 18{,}000 * 0.91 * (0.0020 + 0.0015) = 57\ \frac{trips}{day}$$

$$VMT\ Reduced\ (\boldsymbol{VR}) = 57 * 4.0 = 228\ \frac{vehicle-miles}{day}$$

$$Daily\ Emissions\ Reduction{:}\ Bike\ Lane = [(57 * \frac{0.37 * 2.04}{2}) +$$

$$(228 * (\frac{0.00 * 81.68}{4} + \frac{0.37 * 5.78}{2} + \frac{0.44 * 2.74}{2} + 1.0 * (.03 + 1.10)))] * \frac{1}{1000} = 0.66\ \frac{kilograms}{day}$$

$$Daily\ Emissions\ Reduction{:}\ Paving\ Shoulder = (1.0 * 0.80 * 18{,}000 * 0.91 * 1.5) * \frac{1}{1000} = 19.66\ \frac{kilograms}{day}$$

$$Total\ Daily\ Emissions\ Reduction = 0.66 + 19.66 = 20.32\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1 + 0.03)^{20} * (0.03)}{(1 + 0.03)^{20} - 1} = 0.0672$$

$$Cost-Effectiveness = \frac{0.0672 * 585000 * 1000}{20.32 * 365} = 5{,}300\ \frac{dollars}{metric\ ton}$$

BUS AND LIGHT RAIL PROJECTS

"Expansion of Public Transportation Programs" and "Mass Transit Alternatives" are committed transportation control measures in the Serious Area CO and PM-10 Plans. These measures reduce CO, TOG, NOx, and PM-10 emissions by reducing the vehicle miles of travel (VMT) driven in single occupant vehicles.

New Bus Service

Bus service on new routes and increased frequency on existing bus routes provide a new level of service and reduce VMT. The daily emissions reduction attributable to the new bus service will be estimated based on the difference between the emissions from the light duty vehicle trips replaced by the bus trips and the sum of the bus emissions from the new service and vehicle emissions from people driving to access the bus.

The vehicle miles of travel replaced (***VMT_{REP}***) by the new bus service will be estimated based on the fraction of riders on the bus who drove to their destination prior to introduction of the new bus service (***F_1***). This fraction will be multiplied by total bus riders and the average trip length replaced by the bus service (***trip length$_1$***). The VMT replaced by bus trips will be multiplied by light duty vehicle emission factors from MOBILE6 and fugitive dust emission factors from PART5 for vehicles traveling on a paved road to estimate the emissions from trips replaced by transit.

The automobile VMT added (***VMT_{ADD}***) by people driving to reach the new transit service will be estimated based on the fraction of riders on the bus who drive to transit (***F_2***). This fraction will be multiplied by total bus riders and the average trip length to reach transit (***trip length$_2$***). The VMT added by automobile trips to reach transit will be multiplied by light duty vehicle emission factors from MOBILE6 and paved road emissions factors from PART5 to estimate the automobile emissions added by trips to reach transit.

The emissions from the bus itself (***BUS***) are equal to the number of miles driven daily by the bus multiplied by the exhaust plus fugitive dust emission factors for the bus. Exhaust emission factors for buses are estimated using MOBILE6. In addition to the exhaust emission factors, a PART5 fugitive dust emission factor is included in the net emission factor. It will be assumed that a bus operates 250 weekdays per year and travels 100 miles per weekday (***VMT_{BUS}***).

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Funding***.
- Fraction of riders who previously drove to their destination (***F_1***). For example, if 75 of 100 bus riders drove vehicles to their destination before introduction of the new bus, F_1 would equal 0.75. Default = 0.5 (CARB).
- Fraction of riders who drive to reach transit (***F_2***). For example, if 10 of 100 riders of the new bus drive to reach the bus, F_2 would equal 0.10. Default = 0.03 (Valley Metro, 2001 On Board Origin and Destination Survey).
- Average length of trip from home to destination (***trip length$_1$***). Default = 10.6 miles (from 2001 Maricopa Regional Household Travel Survey and 2002 transportation model validation, February 15, 2005).
- Total daily ridership of each new bus (***R***). For example, if the new bus is expected to carry 400 people per day, *R* would equal 400. Default = 307 (Valley Metro).
- Average length of trip driving from home to transit (***trip length$_2$***). Default = 5 miles (Valley Metro, 2001 On Board Origin and Destination Survey).

Formulas:

$$\textit{VMT Replaced } (\boldsymbol{VMT_{REP}}) = R * F_1 * \textit{trip length}_1$$

$$\textit{VMT added } (\boldsymbol{VMT_{ADD}}) = R * F_2 * \textit{trip length}_2$$

where: $\boldsymbol{R}$ = the ridership on the bus per operating day

$\boldsymbol{F_1}$ = the fraction of riders on the bus who previously drove

trip length$_1$ = the average trip length replaced for each rider who previously drove

$\boldsymbol{F_2}$ = the fraction of riders who drive to transit

trip length$_2$ = the average trip length driven to transit

$$Vehicle\ Emissions\ Reduced\ (\boldsymbol{VER}) = (\boldsymbol{VMT_{REP}} - \boldsymbol{VMT_{ADD}}) * (\frac{w1 * LEF_{CO}}{4} + \frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} +$$

$$(w4 * (LEF_{PM} + PEF))) * \frac{1}{1000} * \frac{250}{365} = \frac{kilograms}{day}$$

where: $\boldsymbol{VMT_{REP}}$ = the vehicle travel replaced by bus service

$\boldsymbol{VMT_{ADD}}$ = the VMT added as a result of trips driven to reach transit

LEF = the light duty vehicle emission factor for each pollutant

PEF = the paved road PM-10 emission factor for all road types

250/365 = the factor to convert weekdays to an annual average day

w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively

$$Bus\ Emissions\ (\boldsymbol{BUS}) =$$

$$(\frac{w1 * BEF_{CO}}{4} + \frac{w2 * BEF_{TOG}}{2} + \frac{w3 * BEF_{NOx}}{2} + (w4 * (BEF_{PM} + PEF))) * VMT_{BUS} * \frac{1}{1000} * \frac{250}{365} = \frac{kilograms}{day}$$

where: ***BEF*** = the bus exhaust emission factor for each pollutant (includes tire wear and brake wear for PM-10)

$\boldsymbol{VMT_{BUS}}$ = the daily bus VMT

$$Daily\ Emissions\ Reduction = \boldsymbol{VER} - \boldsymbol{BUS} = \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent

life = effectiveness period of 12 years (CARB, 2005)

$$Cost\text{-}Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ\ Cost} * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

<u>New Bus Service EXAMPLE</u>

A city proposes to purchase a diesel bus to start a new bus route in 2005. The cost of the bus is \$320,000. The city proposes to pay \$32,000 and requests \$288,000 of CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = \$288,000.
- Fraction of riders who previously drove to their destination ($\boldsymbol{F_1}$) = 0.5.
- Fraction of riders who drive to reach transit ($\boldsymbol{F_2}$) = 0.03.
- Average length of trip from home to destination ($\boldsymbol{trip\ length_1}$) = 10.6 miles.
- Total daily ridership on the new bus ($\boldsymbol{R}$) = 307.
- Average length of trip from home to transit ($\boldsymbol{trip\ length_2}$) = 5 miles.

Calculations:

$$\boldsymbol{VMT_{REP}} = 307 * 0.50 * 10.6 = 1{,}627$$

$$\boldsymbol{VMT_{ADD}} = 307 * 0.03 * 5 = 46$$

$$\boldsymbol{VER} = (1{,}627 - 46) * (\frac{0.00 * 10.92}{4} + \frac{0.37 * 1.11}{2} + \frac{0.44 * 0.92}{2} + (1.0 * (0.03 + 0.79))) * \frac{1}{1000} * \frac{250}{365} = 1.33\ \frac{kilograms}{day}$$

$$\boldsymbol{BUS} = 100 * (\frac{0.00 * 2.84}{4} + \frac{0.37 * 0.23}{2} + \frac{0.44 * 14.60}{2} + (1.0 * (0.19 + 0.79))) * \frac{1}{1000} * \frac{250}{365} = 0.29\ \frac{kilograms}{day}$$

$$Daily\ Emissions\ Reduction = 1.33 - 0.29 = 1.04\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+0.03)^{12} * (0.03)}{(1+0.03)^{12} - 1} = 0.1005$$

$$Cost\text{-}Effectiveness = \frac{0.1005 * 288{,}000 * 1000}{1.04 * 365} = 76{,}249 \ \frac{dollars}{metric\ ton}$$

<u>New Light Rail Service</u>

Light rail represents a new alternative mode to single occupant vehicle travel. Light rail service will decrease emissions by reducing vehicle miles of travel. The daily emissions reduction attributable to the provision of new rail service or the improvement of existing service will be based on the estimated number of light rail passengers who previously drove in single occupant vehicles. Emissions from light rail passengers driving to access the light rail stations will be deducted from the benefit.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Funding (total for the rail segment being funded)***.
- Fraction of riders who previously drove to their destination ($\boldsymbol{F_1}$). For example, if 50 of 100 rail riders drove vehicles to their destination before introduction of the new rail service, F_1 would equal 0.5.
- Fraction of riders who drive to reach rail ($\boldsymbol{F_2}$). For example, if 20 of 100 riders drive to reach the rail line, F_2 would equal 0.20.
- Average length of trip from home to destination (***trip length***$_1$).
- Total daily ridership on the rail line (***R***). For example, if the new line is expected to carry 30,000 passengers per day, *R* would equal 30,000.
- Average length of trip driving from home to rail (***trip length***$_2$).

Formulas:

$$VMT\ Replaced\ (\boldsymbol{VMT_{REP}}) = R * F_1 * trip\ length_1$$

$$VMT\ added\ (\boldsymbol{VMT_{ADD}}) = R * F_2 * trip\ length_2$$

where: ***R*** = the ridership on the rail segment per average weekday
$\boldsymbol{F_1}$ = the fraction of rail riders who previously drove in a single occupant vehicle
trip length$_1$ = the average trip length replaced for each rider who previously drove
$\boldsymbol{F_2}$ = the fraction of riders who drive to the rail station
trip length$_2$ = the average trip length driven to the rail station

$$\textit{Daily Emissions Reduction} = (\boldsymbol{VMT_{REP}} - \boldsymbol{VMT_{ADD}}) * (\frac{w1 * LEF_{CO}}{4} + \frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} +$$

$$(w4 * (LEF_{PM} + PEF)) * \frac{1}{1000} * \frac{250}{365} = \frac{kilograms}{day}$$

where: $\boldsymbol{VMT_{REP}}$ = the vehicle travel replaced by the rail service
$\boldsymbol{VMT_{ADD}}$ = the VMT added as a result of trips driven to the rail station
LEF = the light duty vehicle emission factor for each pollutant
PEF = the paved road PM-10 emission factor for all road types
w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively
250/365 = the factor to convert weekdays to an annual average day

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+i)^{\boldsymbol{life}}\,(i)}{(1+i)^{\boldsymbol{life}} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 20 years

$$\textit{Cost-Effectiveness} = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ\ Cost} * 1000}{\textit{Daily Emissions Reduction} * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

New Light Rail Service **EXAMPLE**

In FY 2006, Valley Metro Rail (VMR) requests $4,000,000 in CMAQ funds to augment the cost of constructing the 20-mile minimum operating segment (MOS) of the new light rail system. VMR estimates that a total of $20 million in supplemental CMAQ funds will be needed to complete the MOS. Transit modeling indicates that 30,000 passengers will ride the MOS on an average weekday during the first full year of operation in 2009. VMR anticipates that 50 percent of the light rail passengers would have previously driven in single occupant vehicles, traveling an average of 10.6 miles from their origin to their destination. Twenty percent of the light rail riders are expected to drive to the light rail station and the average length of these trips is estimated to be 5 miles.

Inputs Required from Entity Requesting CMAQ Funds:

- ***Total CMAQ Cost for MOS*** = \$20,000,000.
- Number of light rail passengers per average weekday ***(R)*** = 30,000.
- Fraction of riders who previously drove to their destination in an SOV (F_1) = 0.50.
- Average length of SOV trips diverted to rail (***trip length***$_1$) = 10.6 miles.
- Fraction of riders who drive to the rail station (F_2) = 0.20.
- Average length of trips driven to the rail station (***trip length***$_2$) = 5 miles.

$$\text{VMT Replaced } (\mathbf{VMT_{REP}}) = 30{,}000 * 0.5 * 10.6 = 159{,}000$$

$$\text{VMT added } (\mathbf{VMT_{ADD}}) = 30{,}000 * 0.2 * 5.0 = 30{,}000$$

$$\text{Daily Emissions Reduction} = (159{,}000 - 30{,}000) * (\frac{0.00 * 9.22}{4} + \frac{0.37 * 0.79}{2} + \frac{0.44 * 0.60}{2} +$$

$$(1.0 * (0.03 + 0.79))) * \frac{1}{1000} * \frac{250}{365} = 97.03 \frac{kilograms}{day}$$

$$\text{Capital Recovery Factor } (\mathbf{CRF}) = \frac{(1+0.03)^{20} * (0.03)}{(1+0.03)^{20} - 1} = 0.0672$$

$$\text{Cost-Effectiveness} = \frac{0.0672 * 20{,}000{,}000 * 1000}{97.03 * 365} = 37{,}949 \frac{dollars}{metric\ ton}$$

DIESEL RETROFITS

FHWA has indicated that retrofits to diesel engines that reduce emissions are eligible for CMAQ funding (FHWA, 2003). Diesel retrofit projects typically involve installing catalyst devices and particulate filters on diesel vehicles manufactured after 1990. Retrofits to diesel vehicles can effect significant reductions in tailpipe emissions of NOx and PM-10.

Diesel retrofits will be quantified by comparing emissions before and after the application of the retrofit emission control technology. MOBILE6 will be run to estimate CO, TOG, NOx, and PM-10 emission rates for heavy duty diesel vehicles in the year of project implementation. Emission rates for each model year of vehicle being retrofitted will be multiplied by the annual vehicle miles traveled. The resultant emissions will be compared with MOBILE6 emissions for a heavy duty diesel vehicle manufactured in 2010. The difference will represent the emissions benefit of the diesel retrofit project. It is expected that the vehicles that are retrofitted will be kept in service for at least five years.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Model year(s) of the vehicles to be retrofitted.
- Average annual mileage traveled by the vehicles being retrofitted.

Formulas:

$$Emissions\ Before\ Retrofit\ (EBR_i) = \boldsymbol{VMT_i} * \left(\frac{w1 * BEF_{CO}}{4} + \frac{w2 * BEF_{TOG}}{2} + \frac{w3 * BEF_{NOx}}{2} + (w4 * BEF_{PM10})\right)$$

$$Emissions\ After\ Retrofit\ (EAR) = \sum VMT_i * \left(\frac{w1 * AEF_{CO}}{4} + \frac{w2 * AEF_{TOG}}{2} + \frac{w3 * AEF_{NOx}}{2} + (w4 * AEF_{PM10})\right)$$

where: $\boldsymbol{VMT_i}$ = the annual miles driven by vehicles of model year i
BEF = the heavy duty diesel emission factor for each pollutant in model year i
AEF = the heavy duty diesel emission factor for each pollutant in model year 2010
w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively

$$Daily\ Emissions\ Reduction = \left(\sum \boldsymbol{EBR_i} - \boldsymbol{EAR}\right) * \frac{1}{1000} * \frac{1}{365} = \frac{kilograms}{day}$$

where: **1/365** = factor to convert annual emissions to daily emissions

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: i = discount rate of 3 percent
life = effectiveness period of 5 years

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

A city requests $350,000 in FY 2011 CMAQ funds to retrofit 40 heavy duty diesel vehicles in the municipal fleet with oxidation catalysts and particulate filters. The city will provide a $50,000 cash match for the project. The model years of the vehicles to be retrofitted range from 1995 to 1999. The average annual miles driven by each vehicle is 20,000. The city commits to use the retrofitted vehicles for at least five more years.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $350,000.
- Model year [# of vehicles] = 1996 [10], 1997 [7], 1998 [8], 1999 [15].
- Average annual miles driven per vehicle = 20,000.

Calculations:

$$EBR_{1996} = 200{,}000 * \left(\frac{0.00 * 4.41}{4} + \frac{0.37 * 0.95}{2} + \frac{0.44 * 17.89}{2} + (1.00 * 0.81)\right) = 984{,}310 \ \frac{grams}{year}$$

$$EBR_{1997} = 140{,}000 * \left(\frac{0.00 * 3.87}{4} + \frac{0.37 * 0.86}{2} + \frac{0.44 * 17.92}{2} + (1.00 * 0.71)\right) = 673{,}610 \ \frac{grams}{year}$$

$$EBR_{1998} = 160{,}000 * \left(\frac{0.00 * 3.50}{4} + \frac{0.37 * 0.80}{2} + \frac{0.44 * 17.74}{2} + (1.00 * 0.62)\right) = 747{,}328 \ \frac{grams}{year}$$

$$EBR_{1999} = 300{,}000 * \left(\frac{0.00 * 3.29}{4} + \frac{0.37 * 0.74}{2} + \frac{0.44 * 17.35}{2} + (1.00 * 0.54)\right) = 1{,}348{,}170 \ \frac{grams}{year}$$

$$EAR = 800{,}000 * \left(\frac{0.00 * 1.02}{4} + \frac{0.37 * 0.35}{2} + \frac{0.44 * 4.75}{2} + (1.00 * 0.17)\right) = 1{,}023{,}800 \ \frac{grams}{year}$$

$$Daily\ Emissions\ Reduction = (3{,}753{,}418 - 1{,}023{,}800) * \frac{1}{1000} * \frac{1}{365} = 7.48 \ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1 + 0.03)^5 * (0.03)}{(1 + 0.03)^5 - 1} = 0.2184$$

$$Cost\text{-}Effectiveness = \frac{0.2184 * 350{,}000 * 1000}{7.48 * 365} = 27{,}998 \ \frac{dollars}{metric\ ton}$$

FREIGHT PROJECTS

FHWA has indicated that projects that reduce emissions from vehicles involved in the movement of freight are eligible for CMAQ funding (FHWA, 2003). One example might be a public-private partnership to implement a truck stop electrification project within the nonattainment area. Reductions in vehicle idling or miles traveled by heavy duty diesel vehicles reduce NOx and PM-10 emissions.

To quantify the benefit of a freight project, MOBILE6 will be run to estimate CO, TOG, NOx, and PM-10 emission rates for heavy duty diesel vehicles in the year of project implementation. If the project reduces vehicle miles of travel (VMT), heavy duty diesel emission rates at 30 mph will be multiplied by the estimated annual reduction in VMT. If the project reduces vehicle idling, MOBILE6 emission rates for heavy duty diesel vehicles operating at 2.5 miles per hour will be multiplied by the estimated annual reduction in idling hours. The resultant emissions will represent the emissions benefit of the freight project.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Annual vehicle miles of travel or idling hours reduced.

Formulas:

$$Daily\ Emissions\ Reduction = \boldsymbol{R} * \left(\frac{w1 * DEF_{CO}}{4} + \frac{w2 * DEF_{TOG}}{2} + \frac{w3 * DEF_{NOx}}{2} + (w4 * DEF_{PM10})\right) * \frac{1}{1000} * \frac{1}{365}$$

where: ***R*** = annual vehicle miles of travel or idling hours reduced by the project
DEF = the heavy duty diesel emission factor for each pollutant at 30 mph (for VMT reductions) or 2.5 mph (for reductions in idling)
1/365 = factor to convert annual emissions to daily emissions

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{\boldsymbol{life}}\ (i)}{(1+i)^{\boldsymbol{life}} - 1}$$

where: *i* = discount rate of 3 percent
life = effectiveness period of 5 years

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

A city enters into a legal agreement with a private firm to build 50 electrified stalls at a truck stop within the city limits. Emissions will be reduced because trucks using the stalls will turn off their engines and receive compartment cooling/heating and other services (cable TV, high speed internet) during rest stops. The total cost of the project is estimated to be $1,000,000. The city will donate land appraised at $100,000 to accommodate the 50 electrified stalls. The city requests $500,000 in FY 2011 CMAQ funds. The private firm has committed to pay the remaining capital cost of the project. It is estimated that idling at the truck stop will be reduced by 50,000 hours per year.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $500,000.
- Annual hours of idling reduced = 50,000.

Calculations:

$$\textit{Daily Emissions Reduction} = 50{,}000 * \left(\frac{0.00 * 12.49}{4} + \frac{0.37 * 2.80}{2} + \frac{0.44 * 21.67}{2} + (1.00 * 0.42)\right) * \frac{1}{1000} * \frac{1}{365} = 0.78\ \frac{\textit{kilograms}}{\textit{day}}$$

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1 + 0.03)^5 * (0.03)}{(1 + 0.03)^5 - 1} = 0.2184$$

$$\textit{Cost-Effectiveness} = \frac{0.2184 * 500{,}000 * 1000}{0.78 * 365} = 383{,}562\ \frac{\textit{dollars}}{\textit{metric ton}}$$

HIGH OCCUPANCY VEHICLE FACILITIES

"Promotion of High Occupancy Vehicle Lanes and By-Pass Ramps" is a committed control measure in the MAG 1999 Serious Area CO and PM-10 Plans. High occupancy vehicle (HOV) facilities reduce emissions by reducing congestion and encouraging higher auto occupancies during peak traffic periods.

The MOBILE6 model will be run for the year that the HOV facility is scheduled to be open to traffic. Light duty vehicle emissions of CO, TOG, and NOx ($\boldsymbol{LEF_{CO}}$, $\boldsymbol{LEF_{TOG}}$, and $\boldsymbol{LEF_{NOx}}$) in grams per mile will be estimated for the AM and PM peak periods with and without the HOV improvement. The VMT and speeds will be obtained from MAG AM and PM peak period EMME/2 traffic assignments with and without the HOV improvement. The VMTs and speeds will be tabulated only for the planning districts in which the HOV improvement occurs. The emission factors with and without the HOV improvement will be multiplied by the change in peak period VMT to quantify the emissions benefit of the HOV project. VMT increases due to the HOV facility will be assumed to be attributable to traffic diverted from arterials to freeways. The VMT increase will be multiplied by the difference between the emission rate for PM-10 reentrained by vehicles traveling on arterials (1.10 grams/mile) versus freeways (0.16 grams per mile). This PM-10 emission reduction will be added to the emissions benefit for CO, TOG, and NOx.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Length and location of HOV improvement in sufficient detail for EMME/2 network coding.

Formulas:

$$Emissions\ with\ HOV\ (EH)\ =\ \boldsymbol{VMT_{HOV}}\ *\ 0.91\ *$$

$$\left(\frac{w1 * LEF_{CO-HOV}}{4} + \frac{w2 * LEF_{TOG-HOV}}{2} + \frac{w3 * LEF_{NOx-HOV}}{2}\right) * \frac{1}{1000}$$

where: $\boldsymbol{VMT_{HOV}}$ **=** AM plus PM peak period VMT in districts with HOV improvement
0.91 = factor to convert from weekday VMT to annual average daily VMT
$\boldsymbol{LEF_{CO-HOV}}$ = CO emission factor for average peak period speed with HOV
$\boldsymbol{LEF_{TOG-HOV}}$ = TOG emission factor for average peak period speed with HOV
$\boldsymbol{LEF_{NOx-HOV}}$ = NOx emission factor for average peak period speed with HOV
w1-w3 = weighting factors for CO, TOG, and NOx respectively

$$Emissions\ w/No\ HOV\ (ENH)\ =\ \boldsymbol{VMT_{NonHOV}}\ *\ 0.91\ *$$

$$\left(\frac{w1 * LEF_{CO-NonHOV}}{4} + \frac{w2 * LEF_{TOG-NonHOV}}{2} + \frac{w3 * LEF_{NOx-NonHOV}}{2}\right) * \frac{1}{1000}$$

where: $\boldsymbol{VMT}_{NonHOV}$ = AM and PM VMT in same districts without HOV improvement
$\boldsymbol{LEF_{CO-NonHOV}}$ = CO emission factor for average peak period speed without HOV
$\boldsymbol{LEF_{TOG-NonHOV}}$ = TOG emission factor for average peak period speed without HOV
$\boldsymbol{LEF_{NOx-NonHOV}}$ = NOx emission factor for average peak period speed without HOV

$$PM-10\ Reduction\ (PR)\ =\ 0.91\ *\ (\boldsymbol{VMT_{HOV}} - \boldsymbol{VMT_{Non-HOV}})\ *\ 0.94\ \frac{grams}{mile}\ *\ w4\ *\ \frac{1}{1000}$$

where: **0.94** = Difference between the PM-10 reentrainment rate on arterials and freeways (1.10 g/mi - 0.16 g/mi)
w4 = weighting factor for PM-10

$$\textit{Daily Emissions Reduction} = (\boldsymbol{ENH} - \boldsymbol{EH} + \boldsymbol{PR}) = \frac{kilograms}{day}$$

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+i)^{\boldsymbol{life}}\ (i)}{(1+i)^{\boldsymbol{life}} - 1}$$

where: i = discount rate of 3 percent
life = effectiveness period of 20 years

$$\textit{Cost-Effectiveness} = \frac{\boldsymbol{CRF} * \underline{\boldsymbol{CMAQ}}\ \textit{Cost} * 1000}{\textit{Daily Emissions Reduction} * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

High Occupancy Vehicle Lanes EXAMPLE

ADOT requests $2,829,000 in FY 2010 CMAQ funds to construct an additional HOV lane in each direction on a three mile segment of I-10. Using the EMME/2 transportation models, MAG simulates AM and PM peak period traffic for 2010 with and without the proposed HOV lanes. The AM and PM peak period traffic assignments indicate that the planning districts containing the HOV improvement have a total peak VMT of 21,868,069 per weekday and an average peak period speed of 29.1 mph. Without the HOV lanes, the AM and PM peak period traffic assignments indicate that total peak period VMT in the comparable area is 21,799,412 and the average peak period speed is 28.1 mph.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $2,829,000.

Calculations:

$$\textit{Emissions with HOV Improvement } (EH) = 21{,}868{,}069 * 0.91 *$$

$$\left(\frac{0.00 * 8.03}{4} + \frac{0.37 * 0.72}{2} + \frac{0.44 * 0.55}{2}\right) * \frac{1}{1000} = 5{,}058.57\ \frac{kilograms}{day}$$

$$Emissions\ with\ No\ HOV\ Improvement\ (\boldsymbol{ENH}) = 21{,}799{,}412 * 0.91 *$$

$$(\frac{0.00 * 7.98}{4} + \frac{0.37 * 0.72}{2} + \frac{0.44 * 0.55}{2}) * \frac{1}{1000} = 5{,}042.68\ \frac{kilograms}{day}$$

$$PM\text{-}10\ Reduction\ (\boldsymbol{PR}) = 0.91 * (21{,}868{,}069 - 21{,}799{,}412) * 0.94 * 1.0 * \frac{1}{1000} = 58.73\ \frac{kilograms}{day}$$

$$Daily\ Emissions\ Reduction = (5{,}042.68 - 5{,}058.57 + 58.73) = 42.84\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+0.03)^{20} * (0.03)}{(1+0.03)^{20} - 1} = 0.0672$$

$$Cost\text{-}Effectiveness = \frac{.0672 * 2{,}829{,}000 * 1000}{42.84 * 365} = 12{,}158\ \frac{dollars}{metric\ ton}$$

INTERSECTION IMPROVEMENTS

Intersection improvements include projects which add left or right turn lanes or construct roundabouts to improve traffic flow. These improvements reduce vehicle delay and idling emissions. If an entity requesting CMAQ funds provides the total weekday or peak period vehicle delay before and after the intersection improvement, based on traffic operations modeling, or the average morning and evening peak period queue lengths before the intersection improvement, based on recent traffic counts, then this data will be utilized in estimating the emission reductions. Otherwise, average queue lengths will be derived from the most recent MAG congestion study. When data are not provided by the local jurisdiction, the vehicle delay associated with the addition of a second or third turn lane will be calculated using average queue lengths ($\boldsymbol{Q}_{am}$,$\boldsymbol{Q}_{pm}$) for the morning (7 to 9 a.m.) and evening (4 to 6 p.m.) peak periods in the adjacent turn lane before the improvement. Similarly, the delay at an intersection where a right or left turn lane will be added and there currently is none (i.e., the adjacent lane accommodates both right and through or left and through movements) will be calculated using the morning and evening peak period queue lengths ($\boldsymbol{Q}_{am}$,$\boldsymbol{Q}_{pm}$) for the adjacent through lane and the average turning movement percent (***TM***) before the improvement.

If one turn lane is added, it will be assumed that vehicle delay will be reduced (***RF***) by 40 percent. If two lanes are added, ***RF*** will equal 70 percent. For roundabouts, it will be assumed that either one or two new turn lanes are added, depending upon the design capacity. If delay reduction data from traffic operations modeling or queuing data from traffic counts are not provided by the requestor, the AM and PM peak period queue lengths for each intersection will be derived from the latest MAG congestion study. If improvements are proposed for an intersection not included in the congestion study, the queue lengths will be obtained for an intersection with similar traffic characteristics. The total reduction in AM and PM peak period vehicle delay at the intersection will be multiplied by a factor of 2.05 to account for congestion reduction during off-peak as well as peak hours. An idling emission factor will be applied to determine the emission reduction benefit of the intersection improvement. This methodology assumes that reductions in weekday delay are the principal source of emission reductions attributable to an intersection improvement.

MOBILE6 will be run to estimate the average idle emission factors for CO, TOG, NOx, and PM-10 for all vehicle classes in the year of project implementation ($\boldsymbol{IEF_{CO}}$, $\boldsymbol{IEF_{TOG}}$, $\boldsymbol{IEF_{NOx}}$, and $\boldsymbol{IEF_{PM}}$). As recommended in EPA's "Technical Guidance on the Use of MOBILE6 for Inventory Preparation," the idle emission factor will be estimated by running the model at 2.5 miles per hour and converting the resulting emission factor in grams per mile to grams per hour, using 2.5 miles per hour.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.

And optionally:

- Modeled reduction in total weekday or a.m. and p.m. peak period vehicle hours of delay due to the improvement (***R***); or
- Recent counts of average queue lengths in the adjacent lane during the a.m. and p.m. peak periods before the improvement ($\boldsymbol{(Q_{am}, Q_{pm})}$).

Formulas:

When a second or third turn lane is added to an existing turn lane:

$$\textit{Daily Emissions Reduction} =$$

$$\boldsymbol{RF} * 2.05 * (\boldsymbol{Q_{am}} + \boldsymbol{Q_{pm}}) * [\frac{\boldsymbol{w1} * \boldsymbol{IEF_{CO}}}{4} + \frac{\boldsymbol{w2} * \boldsymbol{IEF_{TOG}}}{2} \frac{\boldsymbol{w3} * \boldsymbol{IEF_{NOx}}}{2} + \boldsymbol{w4} * \boldsymbol{IEF_{PM}}] * 0.91 * \frac{1}{1000} = \frac{kilograms}{day}$$

When a turn lane is added, where one did not exist:

$$\textit{Daily Emissions Reduction} =$$

$$\boldsymbol{RF} * 2.05 * (\boldsymbol{Q_{am}} + \boldsymbol{Q_{pm}}) * \boldsymbol{TM} * [\frac{\boldsymbol{w1} * \boldsymbol{IEF_{CO}}}{4} + \frac{\boldsymbol{w2} * \boldsymbol{IEF_{TOG}}}{2} + \frac{\boldsymbol{w3} * \boldsymbol{IEF_{NOx}}}{2} + \boldsymbol{w4} * \boldsymbol{IEF_{PM}}] * 0.91 * \frac{1}{1000} = \frac{kilograms}{day}$$

where: ***RF*** = the delay reduction factor

2.05 = the ratio of total average 24-hour weekday delay per vehicle to the average delay per vehicle during the a.m. and p.m. peak periods

Q_{am} = average queue length for the turning movement in the a.m. peak period before the improvement
Q_{pm} = average queue length for the turning movement in the p.m. peak period before the improvement
TM = the average turning movement percent
IEF = the idling emission factor for all vehicle classes for each pollutant
0.91 = factor to convert from average weekday traffic to annual average daily traffic
w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively

$$\textit{Capital Recovery Factor } (\textbf{\textit{CRF}}) = \frac{(1+i)^{life}\,(i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 20 years

$$\textit{Cost-Effectiveness} = \frac{\textbf{\textit{CRF}} * \textbf{\textit{CMAQ}}\ \textit{Cost} * 1000}{\textit{Daily Emissions Reduction} * 365} = \frac{\textit{dollars}}{\textit{metric ton}}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Additional Turning Lanes — EXAMPLE

A city proposes to add second left turn lanes westbound and northbound and a dedicated right turn lane eastbound at an intersection in 2010 at a cost of $2,000,000. The city proposes to pay $200,000 and requests $1,800,000 of CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $1,800,000.

The city does not provide an estimate of the total reduction in weekday or peak period vehicle hours of delay based on traffic operations modeling or the peak period queue lengths for adjacent lanes, based on recent traffic counts. Therefore, the data in Table 5 was obtained from the 1998 MAG Regional Congestion Study for the intersection to be improved (MAG, 2000b).

Table 5. Queue Lengths for Turning Movements at the Intersection Before Improvements

Approach	Time Period	Left Turn Queue Length	Approach	Time Period	Thru/Right Turn Queue Length
East	7-8 a.m.	9.90	West	7-8 a.m.	20.00
East	8-9 a.m.	9.50	West	8-9 a.m.	11.00
East	4-5 p.m.	8.54	West	4-5 p.m.	14.18
East	5-6 p.m.	9.38	West	5-6 p.m.	20.69
South	7-8 a.m.	9.34			
South	8-9 a.m.	8.84			
South	4-5 p.m.	9.00			
South	5-6 p.m.	9.76			

- For the additional westbound left turn lane, $\boldsymbol{Q_{am}}$ = 19.40 and $\boldsymbol{Q_{pm}}$ = 17.92 (from Table 5).
- For the additional northbound left turn lane, $\boldsymbol{Q_{am}}$ = 18.18 and $\boldsymbol{Q_{pm}}$ = 18.76 (from Table 5).
- For the new eastbound right turn lane, $\boldsymbol{Q_{am}}$ = 31.00 and $\boldsymbol{Q_{pm}}$ = 34.87 (from Table 5), and the average right turning movement percentage, ***TM*** = 15%.

Calculations:

For the additional westbound left turn lane:

$$\textit{Daily Emissions Reduction} =$$

$$0.40 * 2.05 * (19.40 + 17.92) * (\frac{0.00 * 47.62}{4} + \frac{0.37 * 11.94}{2} + \frac{0.44 * 5.05}{2} + (1.0 * 0.11)) * 0.91 * \frac{1}{1000} = 0.10 \ \frac{\textit{kilograms}}{\textit{day}}$$

For the additional northbound left turn lane:

$$\textit{Daily Emissions Reduction} =$$

$$0.40 * 2.05 * (18.18 + 18.76) * (\frac{0.00 * 47.62}{4} + \frac{0.37 * 11.94}{2} + \frac{0.44 * 5.05}{2} + (1.0 * 0.11)) * 0.91 * \frac{1}{1000} = 0.09 \ \frac{\textit{kilograms}}{\textit{day}}$$

For the new eastbound right turn lane:

$$\textit{Daily Emissions Reduction} =$$

$$0.40 * 2.05 * (31.00 + 34.87) * 0.15 * (\frac{0.00 * 47.62}{4} + \frac{0.37 * 11.94}{2} + \frac{0.44 * 5.05}{2} + (1.0 * 0.11)) * 0.91 * \frac{1}{1000} = 0.03 \frac{\textit{kilograms}}{\textit{day}}$$

Total vehicle delay reduced on an average weekday due to the addition of the three new lanes would be 68.99 hours. The total daily emissions reduction would be 0.22 kilograms/day.

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+0.03)^{20} * (0.03)}{(1+0.03)^{20} - 1} = 0.0672$$

$$\textit{Cost-Effectiveness} = \frac{0.0672 * 1{,}800{,}000 * 1000}{0.22 * 365} = 1{,}506{,}351 \ \frac{\textit{dollars}}{\textit{metric ton}}$$

Roundabout **EXAMPLE**

ADOT proposes to build a roundabout in 2010 at a freeway interchange. Traffic operations modeling performed by an ADOT consultant indicates that the roundabout will reduce average vehicle delay by 120 hours per average weekday. The cost of the project is $2,200,000. ADOT proposes to pay $200,000 and requests $2,000,000 of CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $2,000,000.

Since the requestor has provided the modeled estimate of 120 hours of vehicle delay reduction for an average weekday (***R***), this value will be substituted for **RF**, **2.05,** $\mathbf{Q_{am}}$, $\mathbf{Q_{pm}}$, and **TM** in the equations below:

$$\textit{Daily Emissions Reduction} =$$

$$120 * \left(\frac{0.00 * 47.62}{4} + \frac{0.37 * 11.94}{2} + \frac{0.44 * 5.05}{2} + (1.0 * 0.11)\right) * 0.91 * \frac{1}{1000} = 0.37 \ \frac{\textit{kilograms}}{\textit{day}}$$

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+0.03)^{20} * (0.03)}{(1+0.03)^{20} - 1} = 0.0672$$

$$\textit{Cost-Effectiveness} = \frac{0.0672 * 2{,}000{,}000 * 1000}{0.37 * 365} = 995{,}187 \ \frac{\textit{dollars}}{\textit{metric ton}}$$

OZONE EDUCATION PROGRAM

"Areawide Public Awareness Programs" is a committed control measure in the MAG 1999 Serious Area CO and PM-10 Plans. Past Air Quality Education Programs have been conducted during the winter months for CO and PM-10 and the summer months for ozone. These educational and outreach efforts focus on encouraging the public to reduce single occupant vehicle (SOV) travel, especially during periods of high measured concentrations, called high pollution advisories. Air Quality Educational Program messages are communicated through the news media, television and radio spots, posters, and the Internet. During high pollution advisories, residents are encouraged to take alternate modes, such as carpools, vanpools, buses, bicycles, or walking. Telecommuting and compressed work schedules are also encouraged. These programs reduce emissions primarily by decreasing the total vehicle miles of travel (VMT) for commute trips.

Based on TDM surveys conducted in 1999-2003 for RPTA, an average of 26 percent of commute trips by persons not employed at home were taken by an alternate mode, including telecommuting and compressed work schedules (RPTA, 2003). The average trip length of commute trips by all modes for 1999-2001 was 12.6 miles (RPTA, 2001).[7]

The MOBILE6 model will be run for the CMAQ funding year to estimate the average light duty vehicle emissions of TOG, NOx, and PM-10 ($\boldsymbol{LEF_{TOG}}$, $\boldsymbol{LEF_{NOx}}$, and $\boldsymbol{LEF_{PM}}$) in grams per mile. The emission factors are multiplied by the reduction in vehicle miles of travel (***VR***) to estimate the daily emissions reduction benefit of the Ozone Education Program. The CO emission factor is not included because this program is not in operation during the winter CO season. The PM-10 factor is divided by two to reflect the six month duration of the ozone education program.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Percent of alternate mode use attributable to the Ozone Education Program ***(P)***.

Formulas:

$$\textit{VMT Reduced } (\boldsymbol{VR}) = \frac{\mathbf{.26} * \boldsymbol{W} * \boldsymbol{P}}{\mathbf{1.2}} * \mathbf{12.6}$$

where: ***.26*** = 1999-2003 average percent of trips by employees using alternate modes including telecommuting and compressed work schedules (Table 16a, RPTA, 2003)
W = daily home-based work person trips = 1.6 * total employment in Maricopa County for CMAQ funding request year (MAG trip attraction equation)
P = percent of alternate mode use attributable to the Ozone Education Program
1.2 = average vehicle occupancy (derived from Table 15, RPTA, 2001)
12.6 = 1999-2001 average commute trip length by all modes (Table 52, RPTA, 2001)

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[7]Data on commute trip lengths are not available in TDM surveys conducted by RPTA after 2001.

$$Daily\ Emissions\ Reduction = \boldsymbol{VR} * \left(\frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} + \frac{w4 * (LEF_{PM} + PEF)}{2}\right) * \frac{1}{1000} * \frac{\mathbf{250}}{\mathbf{365}} = \frac{kilograms}{day}$$

where: ***LEF*** = the light duty vehicle emission factor for each pollutant
PEF = the paved road PM-10 emission factor for all road types
w2-w4 = weighting factors for TOG, NOx, and PM-10, respectively
250/365 = factor to convert from an average weekday to an annual average day

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent
life = program period of 1 year

$$Cost\text{-}Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project

Ozone Education Program **EXAMPLE**

RPTA requests $300,000 in FY 2010 CMAQ funds for the Ozone Education Program and indicates that the share of the annual alternative mode use attributable to the Ozone Education Program is ten percent. Based on interim projections accepted by the MAG Regional Council in June 2003, the total employment for Maricopa County in 2010 is expected to be 2,112,000.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $300,000.
- ***P*** = 10%.

Calculations:

$$VMT\ Reduced\ (\boldsymbol{VR}) = \frac{.26 * (1.6 * 2{,}112{,}000) * .10}{1.2} * 12.6 = 922{,}522$$

$$Daily\ Emissions\ Reduction = 922{,}522 * \left(\frac{0.37*0.73}{2} + \frac{0.44*0.54}{2} + \frac{1.0*(0.03+0.79)}{2}\right) * \frac{1}{1000} * \frac{250}{365} = 419.46\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+0.03)^1 * (0.03)}{(1+0.03)^1 - 1} = 1.03$$

$$Cost-Effectiveness = \frac{1.03 * 300{,}000 * 1000}{419.46 * 365} = 2{,}018\ \frac{dollars}{metric\ ton}$$

PARK AND RIDE FACILITIES

"Park and Ride Lots" is a committed control measure in the MAG 1999 Serious Area CO and PM-10 Plans. Park and ride facilities reduce vehicle trips and emissions by encouraging carpooling, vanpooling, and transit ridership. These projects reduce light duty vehicle exhaust emissions of CO, TOG, and NOx, and exhaust plus reentrained emissions of PM-10.

The methodology is based on the number of park and ride spaces to be built and the projected utilization rate in the year that the facility is scheduled to open. It is assumed that each vehicle parked in the facility (spaces times the utilization rate) represents two commute trips. An average trip length is derived from regional commuting data collected by the Regional Public Transportation Authority and applied to the total commute trips. The average trip length driven to park and ride lots (from a MAG park-and-ride lot survey) is subtracted from the average commute trip length. The net trip length is applied to the total commute trips reduced to obtain the average weekday reduction in vehicle miles of travel (VMT).

The MOBILE6 model will be run for the year that the project is implemented to estimate the average light duty vehicle emission factors for CO, TOG, NOx, and PM-10 ($\boldsymbol{LEF_{CO}}$, $\boldsymbol{LEF_{TOG}}$, $\boldsymbol{LEF_{NOx}}$, and $\boldsymbol{LEF_{PM}}$).

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Number of spaces ***(S)***.
- Projected utilization rate ***(U)*** when the facility opens.

Formulas:

$$VMT\ Reduced\ (\boldsymbol{VR}) = \boldsymbol{S} * \boldsymbol{U} * \mathbf{2} * (\mathbf{12.6} - \mathbf{3.5})$$

where: ***S*** = number of parking spaces provided in the park and ride facility
U = average weekday utilization rate in the year that the facility opens
2 = number of vehicle commute trips per average weekday
12.6=1999-2001 average commute trip length by all modes (Table 52, RPTA, 2001)
3.5 =average miles driven to park and ride lots (from MAG park-and-ride lot survey)

$$Daily\ Emission\ Reduction = \boldsymbol{VR} * (\frac{w1 * LEF_{CO}}{4} + \frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} +$$

$$w4 * (LEF_{PM} + PEF)) * \frac{1}{1000} * \frac{250}{365} = \frac{kilograms}{day}$$

where: ***LEF*** = the light duty vehicle emission factor for each pollutant
PEF = the paved road PM-10 emission factor for all road types
250/365 = factor to convert from a weekday to an annual average day
w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{\boldsymbol{life}}\ (i)}{(1+i)^{\boldsymbol{life}} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 20 years

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ\ Cost} * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Park and Ride Lot **EXAMPLE**

The City of Phoenix requests $200,000 in FY 2010 CMAQ funds to construct a park and ride lot with 300 spaces. The City will use an additional $50,000 in local funds. Phoenix estimates that 75 percent of these spaces will be utilized during a typical weekday when the project opens.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost =*** $200,000.
- **S** = 300.
- **U** = 75%.

$$VMT\ Reduced\ (\boldsymbol{VR}) = 300 * 0.75 * 2 * 9.1 = 4{,}095$$

$$Emissions\ Reduction = 4{,}095 * (\frac{0.00 * 8.51}{4} + \frac{0.37 * 0.73}{2} + \frac{0.44 * 0.54}{2} + (1.0 * (0.03 + 0.79))) * \frac{1}{1000} * \frac{250}{365} = 3.01\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1 + 0.03)^{20} * (0.03)}{(1 + 0.03)^{20} - 1} = 0.0672$$

$$Cost-Effectiveness = \frac{0.0672 * 200{,}000 * 1000}{3.01 * 365} = 12{,}233\ \frac{dollars}{metric\ ton}$$

PAVING PROJECTS

"Reduce Particulate Emissions from Unpaved Roads and Alleys," "Reduce Particulate Emissions from Unpaved Shoulders on Targeted Arterials," "Paving, Vegetating and Chemically Stabilizing Unpaved Access Points Onto Paved Roads (Especially Adjacent to Construction/Industrial Sites)," and "Curbing, Paving or Stabilizing Shoulders on Paved Roads (Includes Painting Stripe on Outside of Travel Lane)" are committed control measures in the Revised MAG 1999 Serious Area PM-10 Plan. Paving projects are effective in reducing PM-10 and therefore, represent potential candidates for CMAQ funds. Typical projects requesting CMAQ funds are for paving unpaved shoulders, curbs and gutters, unpaved roads, and unpaved access points. These projects reduce PM-10, but not CO, TOG, or NOx.

The Serious Area PM-10 Plan assumed an unpaved road emission rate of 573.91 grams per vehicle mile of travel (**BEF**) and a paved road emission rate of 1.59 grams per vehicle mile of travel (**AEF**) on low volume roads (i.e., those carrying less than 10,000 vehicles per day) (MAG, 2000a). The difference between the paved and unpaved emission rates (i.e. 572.32 g/vmt) represents the reduction in PM-10 emissions due to paving of dirt roads.

Consistent with the methodology used in the Particulate Control Measure Feasibility Study (MAG, 1997), projects involving the paving of unpaved shoulders or installing curbs and gutters will be assumed to reduce roadway PM-10 emissions by 50 percent. Assuming that a road without a paved shoulder or curb and gutter carries less than 10,000 vehicles per day, stabilizing a dirt shoulder by paving the shoulder or adding curb and gutter will reduce emissions by 0.80 grams per vehicle mile.

As in the Serious Area PM-10 Plan, paving unpaved access points will be assumed to reduce emissions by 41 grams per access point per day. If the number of access points to be paved is not supplied, it will be assumed that eight access points were paved per project mile.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Project length (***centerline miles***).
- Average weekday traffic (***ADT)*** for paving unpaved roads or shoulders.
- The number of access points to be paved (***access points***) - if paving unpaved access points.
- Whether or not the project includes paving the shoulder or providing curb and gutter.

Formulas:

For Paving Unpaved Shoulders or Providing Curb and Gutter:

$$\textit{Daily Emissions Reduction} = w4 * \frac{0.80 \textit{ grams}}{\textit{vehicle mile}} * \boldsymbol{miles} * \boldsymbol{ADT} * 0.91 * \frac{1}{1000} = \frac{\textit{kilograms}}{\textit{day}}$$

where: ***miles*** = the length of the project
ADT = the average weekday traffic
0.91 = the factor to convert to annual average daily traffic
w4 = the PM-10 weighting factor

For Paving Unpaved Roads:

$$\textit{Daily Emissions Reduction} = \boldsymbol{w4} * (\boldsymbol{UEF} - \boldsymbol{PEF}) * \boldsymbol{miles} * \boldsymbol{ADT} * 0.91 * \frac{1}{1000} = \frac{\textit{kilograms}}{\textit{day}}$$

where: ***miles*** = the length of the road
ADT = the average weekday traffic on the road to be paved
0.91 = the factor to convert from weekday to annual average daily traffic
UEF = the emission factor for travel on an unpaved road
PEF = the paved road PM-10 emission factor for roads with low traffic volumes
w4 = the PM-10 weighting factor

For Paving Unpaved Access Points:

$$\textit{Daily Emissions Reduction} = \boldsymbol{w4} * \frac{41 \textit{ grams}}{\textit{access point} - \textit{day}} * \boldsymbol{access\ points} * \frac{1}{1000} = \frac{\textit{kilograms}}{\textit{day}}$$

where: ***access points*** = the number of access points to be paved
w4 = the PM-10 weighting factor

For All Paving Projects:

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 20 years

$$\textit{Cost-Effectiveness} = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ\ Cost} * 1000}{\textit{Daily Emissions Reduction} * 365} = \frac{\textit{dollars}}{\textit{metric ton}}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Paving Unpaved Roads without Paved Shoulders or Curb and Gutter EXAMPLE

A city proposes to pave a 1.5 mile section of unpaved road in FY 2007 which has a weekday traffic volume of 150 vehicles per day. The shoulders will not be paved and there will be no curb and gutter. The city proposes to pay $135,000 and requests $135,000 in CMAQ funds.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $135,000.
- Project length (***miles***) = 1.5 miles.
- Average weekday traffic (***ADT***) on unpaved road = 150.

Calculations:

$$\textit{Daily Emissions Reduction} = 1.0 * (573.91 - 1.59) * 1.5 * 150 * 0.91 * \frac{1}{1000} = 117.18\ \frac{\textit{kilograms}}{\textit{day}}$$

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+0.03)^{20} * (0.03)}{(1+0.03)^{20} - 1} = 0.0672$$

$$\textit{Cost-Effectiveness} = \frac{0.0672 * 135{,}000 * 1000}{117.18 * 365} = 212\ \frac{\textit{dollars}}{\textit{metric ton}}$$

Paving Unpaved Roads With Curb and Gutter **EXAMPLE**

A city proposes to pave a one-mile unpaved road in FY 2007 which currently has a traffic volume of 150 vehicles per average weekday. The city proposes to pay $250,000 and requests $250,000 of CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $250,000.
- Project length (***miles***) = 1 mile.
- Average weekday traffic (***ADT***) on unpaved road = 150.

Calculations:

Calculate the daily emissions reduction from paving the unpaved road:

$$Daily\ Emissions\ Reduction = 1.0 * (573.91 - 1.59) * 1.0 * 150 * 0.91 * \frac{1}{1000} = 78.12\ \frac{kilograms}{day}$$

Calculate the daily emissions reduction from adding the curb and gutter:

$$Daily\ Emissions\ Reduction = 1.0 * 0.80 * 1.0 * 150 * 0.91 * \frac{1}{1000} = 0.11\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+0.03)^{20} * (0.03)}{(1+0.03)^{20} - 1} = 0.0672$$

$$Cost-Effectiveness = \frac{0.0672 * 250{,}000 * 1000}{78.23 * 365} = 588\ \frac{dollars}{metric\ ton}$$

Paving Unpaved Access Points **EXAMPLE**

A city proposes to pave unpaved access points on two miles of road in FY 2007. The city proposes to pay $175,000 and requests $175,000 of CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $175,000.

- Project length (***miles***) = 2 miles.
- Access points to be paved (***access points***): assume default of 8 per mile.

Calculations:

$$Daily\ Emissions\ Reduction\ =\ 1.0\ *\ (\frac{41\ grams}{access\ point-day})\ *\ 16\ *\ \frac{1}{1000}\ =\ 0.66\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF})\ =\ \frac{(1+0.03)^{20}\ (0.03)}{(1+0.03)^{20}\ -\ 1}\ =\ 0.0672$$

$$Cost-Effectiveness\ =\ \frac{0.0672\ *\ 175{,}000\ *\ 1000}{0.66\ *\ 365}\ =\ 48{,}817\ \frac{dollars}{metric\ ton}$$

<u>PM-10 CERTIFIED STREET SWEEPERS</u>

"PM-10 Efficient Street Sweepers" is a committed control measure in the Revised MAG 1999 Serious Area Particulate Plan for PM-10 for the Maricopa County Nonattainment Area (Serious Area PM-10 Plan). Street sweepers certified in accordance with South Coast Air Quality Management District Rule 1186 reduce PM-10 on paved roads, which reduces reentrainment of PM-10 by vehicles traveling on the road. Therefore, the purchase of PM-10 certified street sweepers is eligible for CMAQ funds. Emission reductions for this type of project will be calculated for PM-10 only.

The emission reductions are addressed as two separate components: the reduction in reentrained dust from vehicles traveling on the roadways cleaned by the sweeper and the reduction in dust from the actual sweeping process. These components will be combined to determine the total emissions reduction associated with a PM-10 certified street sweeper. Each component is described in a separate section below.

<u>Reduced Reentrained Dust from Vehicles Traveling on Roadways</u>. If the sweeper is being purchased to replace an existing conventional sweeper, the emission reduction will be based on a comparison of the emissions from the base silt loading on a paved road after using a conventional sweeper versus emissions from the reduced silt loading attributable to a PM-10 certified sweeper. The reduced silt loading results in lower emissions of reentrained dust from vehicles traveling on the road. If the street sweeper is being purchased to increase the frequency of sweeping, the emission reduction will be based on a comparison of emissions using a PM-10 certified sweeper with the new cycle length **(*time*)** versus the same sweeper with the existing cycle length **(*timeold*)**. If the street sweeper is being purchased to expand coverage, the emission reduction will be based on the difference between the

emissions from an unswept road (using the initial emission factors in Tables 6 and 7) and the emissions after sweeping with a PM-10 certified unit for the expanded area (***milesnew***).

The emission factor for reentrained dust varies depending upon how often a street is swept. It will be assumed that requested PM-10 certified street sweepers use the same sweeping schedule as the conventional street sweepers they replace. To be consistent with the Most Stringent Control Measures Analysis in the Serious Area PM-10 Plan (MAG, 1998), it will be assumed that the silt loading on a street returns to its initial level eight days after the street is swept by a PM-10 certified sweeper and three days after being swept by a conventional sweeper. Data from the Most Stringent Measures Analysis (MSM Analysis) also indicates that the PM-10 certified sweepers reduce the initial silt loading by 80 percent (i.e. the silt loading is reduced to 20 percent of the initial level), while conventional sweepers reduce the initial silt loading by 30 percent. The schedule listed in the MSM Analysis for percent of initial silt loading on days after PM-10 certified street sweeping is as follows: day of sweeping - 20 percent, 1 day after - 30 percent, 2 days after - 40 percent, 3 days after - 50 percent, 4 days after - 60 percent, 5 days after - 70 percent, 6 days after - 80 percent, 7 days after - 90 percent, and eight days or more after - 100 percent of initial silt loading. Similarly, the silt loading at varying days after sweeping with a conventional sweeper is as follows: day of sweeping - 70 percent, 1 day after - 80 percent, 2 days after - 90 percent, and 3 days or more after - 100 percent of initial silt loading.

The paved road emission factor for reentrained dust is exponentially related to the silt loading. Therefore, the change in emission factor over time after sweeping does not follow the same linear relationship as shown for silt loading. The emission factors for sweeping freeways and non-freeways with a PM-10 certified unit are listed in Table 6 for various days following street sweeping. Similar factors for a conventional sweeper are provided in Table 7. Based on sweeping frequency, these emission factors will be combined to create a weighted average emission factor as shown in the emission factor formulas below. Separate weighted emission factors will be estimated to reflect the impact of sweeping with PM-10 certified sweepers and conventional sweepers. The difference between these two emission factors is the incremental reduction in emissions achieved by replacing a conventional street sweeper with a PM-10 certified unit. The difference between the initial unswept emission factor and the PM-10 certified sweeper emission factor when applied to the new area being swept (***milesnew***) represents the reduction in emissions achieved by expanding the area of sweeping. The difference between the PM-10 certified emission factors for the old (***timeold***) and new (***time***) cycle lengths represents the reduction achieved by increasing the frequency of sweeping.

<u>Reduced Emissions During the Sweeping Process</u>. The reduction in PM-10 from the actual sweeping process will be based upon the California Air Resources Board estimate that a PM-10 certified street sweeper entrains 0.05 pounds per mile less PM-10 than a conventional sweeper during the sweeping process. For this analysis, the emissions reduction is converted to kilograms per vehicle mile, resulting in an emission reduction factor of 0.023 kilograms per vehicle mile traveled by the PM-10 certified sweeper. This estimate will be combined with the estimate of miles traveled per day by the PM-10 certified sweeper to produce a total reduction in emissions in kilograms for an average day. This reduction will only be applied when a PM-10 certified sweeper will replace a conventional sweeper.

Table 6. Emission factors as a function of days after sweeping with a PM-10 certified sweeper		
	Freeway	Non-freeway
initial (for all days where k ≥ 9)	0.163 g/VMT	1.10 g/VMT
day of sweeping (k=1)	0.057 g/VMT	0.39 g/VMT
1 day after sweeping (k=2)	0.075 g/VMT	0.50 g/VMT
2 days after sweeping (k=3)	0.090 g/VMT	0.61 g/VMT
3 days after sweeping (k=4)	0.104 g/VMT	0.70 g/VMT
4 days after sweeping (k=5)	0.117 g/VMT	0.79 g/VMT
5 days after sweeping (k=6)	0.129 g/VMT	0.87 g/VMT
6 days after sweeping (k=7)	0.141 g/VMT	0.95 g/VMT
7 days after sweeping (k=8)	0.152 g/VMT	1.03 g/VMT
8 days after sweeping (k=9)	0.163 g/VMT	1.10 g/VMT

Table 7. Emission factors as a function of days after sweeping with a conventional sweeper		
	Freeway	Non-freeway
initial (for all days where k ≥4)	0.163 g/VMT	1.10 g/VMT
day of sweeping (k=1)	0.129 g/VMT	0.87 g/VMT
1 day after sweeping (k=2)	0.141 g/VMT	0.95 g/VMT
2 days after sweeping (k=3)	0.152 g/VMT	1.03 g/VMT
3 days after sweeping (k=4)	0.163 g/VMT	1.10 g/VMT

Inputs Required from Entity Requesting CMAQ Funds:

PM-10 certified street sweepers are eligible for purchase with CMAQ funds if they replace an existing unit that has not been certified by South Coast Rule 1186, increase the frequency of sweeping, expand the area that is swept, or a combination of these functions. Input requirements for each of these functions are described below. If the requested unit will perform more than one function, the requestor will need to provide all of the input described under each function. Note that the sweeping cycle (***time*** **or** ***timenew***) referred to below represents the number of calendar days that elapse before the same lane of road is re-swept by the same sweeper.

For all sweeper requests:

- ***CMAQ Cost***.
- Average weekday traffic (***ADT***) per lane on streets to be swept by the PM-10 certified sweeper.
- Whether the requested unit will sweep freeways or non-freeways.

If the new sweeper will replace a noncertified sweeper:

- Current number of days per sweeping cycle (***time***) for the unit being replaced.
- Lane miles (***miles***) swept per cycle by the unit being replaced.

If the new sweeper will be used to increase the frequency of sweeping:

- Planned number of days per sweeping cycle (***timenew***) for the lanes to be swept.
- Current number of days per sweeping cycle (***time***) for the lanes to be swept.
- Lane miles (***miles***) of roads to be swept per cycle.

If the new sweeper will be used to expand the area to be swept:

- Planned number of days per cycle (***timenew***) on roads in the expanded area.
- Lane miles (***milesnew***) of roads to be swept per cycle in the expanded area.

Formulas:

Reduced Reentrained Dust from Vehicles Traveling on Roadways:

Emission factor for roads swept with PM-10 certified street sweepers:

$$PM\text{-}10\ Certified\ Sweeper\ Emission\ Factor\ (\boldsymbol{PEF}) = \frac{\sum_{k=1}^{\boldsymbol{time}} (PM\text{-}10\ certified\ emission\ factor)_k}{\boldsymbol{time}}$$

Emission factor for roads swept with conventional street sweepers:

$$Conventional\ Sweeper\ Emission\ Factor\ (\boldsymbol{CEF}) = \frac{\sum_{k=1}^{\boldsymbol{time}} (conventional\ emission\ factor)_k}{\boldsymbol{time}}$$

where: $(\boldsymbol{PM\text{-}10\ certified\ emission\ factor})_k$ = the emission factor on day k from the table that lists emission factors reflecting the impact of PM-10 certified street sweepers
$(\boldsymbol{conventional\ emission\ factor})_k$ = the emission factor on day k from the table that lists emission factors reflecting the impact of conventional street sweepers

time = current number of days per sweeping cycle

Replacing a Conventional Sweeper:

$$Daily\ Emissions\ Reduction = w4 * \boldsymbol{miles} * \boldsymbol{ADT} * 0.91 * (\boldsymbol{CEF} - \boldsymbol{PEF}) * \frac{1}{1000} = \frac{kilograms}{day}$$

Increasing the Frequency of Sweeping:

$$Daily\ Emissions\ Reduction = w4 * \boldsymbol{miles} * \boldsymbol{ADT} * 0.91 * (\boldsymbol{PEF} - \boldsymbol{PEF_{new}}) * \frac{1}{1000} = \frac{kilograms}{day}$$

Expanding the Coverage of Sweeping:

$$Daily\ Emissions\ Reduction = w4 * \boldsymbol{milesnew} * \boldsymbol{ADT} * 0.91 * (\boldsymbol{IEF} - \boldsymbol{PEF_{new}}) * \frac{1}{1000} = \frac{kilograms}{day}$$

where: ***miles*** = lane miles of street to be swept per cycle in the current area
milesnew = lane miles of streets be swept per cycle in the expanded area
ADT = average weekday traffic per through lane on streets to be swept by the requested sweeper
0.91 = factor to convert from weekday traffic to annual average daily traffic
$\boldsymbol{PEF_{new}}$ = PM-10 certified sweeper emission factor calculated with ***time***= ***timenew***
IEF = the initial silt loading emission factor in Tables 6 and 7
w4 = the PM-10 weighting factor

<u>Reduced Emissions During the Sweeping Process</u> (This reduction is only applied if the requested sweeper replaces a noncertified unit):

$$Daily\ Emissions\ Reduction\ for\ the\ Sweeping\ Process = w4 * (\frac{\boldsymbol{miles}}{\boldsymbol{time}}) * 0.023 = \frac{kilograms}{day}$$

where: **0.023** = kilograms per vehicle mile reduction in reentrained dust from the sweeping process itself.
w4 = the PM-10 weighting factor

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+i)^{\boldsymbol{life}}\,(i)}{(1+i)^{\boldsymbol{life}} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 8 years

$$\textit{Cost-Effectiveness} = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ\ Cost} * 1000}{\textit{Daily Emissions Reduction} * 365} = \frac{\textit{dollars}}{\textit{metric ton}}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

PM-10 Certified Street Sweepers EXAMPLE

A city proposes to purchase a PM-10 certified street sweeper in FY 2006 to replace a noncertified sweeper. The replacement unit will not be used to increase the frequency of sweeping or the area swept. The cost of CMAQ-eligible equipment on the sweeper is $150,000. The city proposes to pay $15,000 and requests $135,000 of CMAQ funding. The certified sweeper will be used on streets (non-freeways) with average weekday traffic per through lane of 5,000 vehicles. Each lane mile of street is currently swept once every 14 days. During this 14-day cycle, 200 lane miles are swept using the noncertified sweeper being replaced.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $135,000.
- Average weekday traffic per through lane swept with the conventional sweeper to be replaced (***ADT***)= 5,000 vehicles/day.
- Current number of days in the sweeping cycle using the conventional sweeper to be replaced (***time***) = 14 days.
- Lane miles of streets swept per sweeping cycle with the conventional sweeper to be replaced (***miles***) = 200 lane miles.

Calculations:

$$\boldsymbol{CEF} = \frac{0.87 + 0.95 + 1.03 + (11 * 1.10)}{14} = 1.068$$

$$\boldsymbol{PEF} = \frac{0.39 + 0.50 + 0.61 + 0.70 + 0.79 + 0.87 + 0.95 + 1.03 + (6 * 1.10)}{14} = 0.889$$

$$\textit{Daily Emissions Reduction for Reentrainment} = 1.0 * 200 * 5000 * 0.91 * (1.068 - 0.889) * \frac{1}{1000} = 162.89 \frac{\textit{kilograms}}{\textit{day}}$$

$$\textit{Daily Emissions Reduction for the Sweeping Process} = 1.0 * \frac{200}{14} * 0.023 = 0.33 \frac{\textit{kilograms}}{\textit{day}}$$

$$\textit{Capital Recovery Factor (CRF)} = \frac{(1+0.03)^8 * (0.03)}{(1+0.03)^8 - 1} = 0.1425$$

$$\textit{Cost-Effectiveness} = \frac{0.1425 * 135{,}000 * 1000}{163.22 * 365} = 323 \frac{\textit{dollars}}{\textit{metric ton}}$$

RIDESHARE PROGRAMS

"Employer Rideshare Program Incentives" and "Preferential Parking for Carpools and Vanpools" are committed control measures in the MAG 1999 Serious Area CO and PM-10 Plans. Ridesharing in carpools and vanpools reduces emissions by decreasing the total vehicle miles of travel (VMT) for commute trips. MAG programs CMAQ funding for the Regional Rideshare Program operated by RPTA and partial funding for the Capitol Rideshare Program conducted by the Arizona Department of Administration.

Based on TDM surveys conducted in 1999-2003 for RPTA, an average of 14 percent of all work trips are made by carpools and vanpools (RPTA, 2003). The average trip length of commute trips by all modes during the period 1999-2001 was 12.6 miles and the average vehicle occupancy was 1.2 (RPTA, 2001).[8]

The MOBILE6 model will be run for the CMAQ funding year to estimate the average light duty vehicle emissions of CO, TOG, NOx, and PM-10 ($\mathbf{LEF_{CO}}$, $\mathbf{LEF_{TOG}}$, $\mathbf{LEF_{NOx}}$, **and** $\mathbf{LEF_{PM}}$) in grams per mile. The emission factors will be multiplied by the reduction in vehicle miles of travel (**VR**) to estimate the emissions benefit of ridesharing.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost.***
- Percent of carpooling participation attributable to the Regional Rideshare Program (**P**).

[8] Data on commute trip lengths and vehicle occupancy are not available in TDM surveys conducted by RPTA after 2001.

Formulas:

$$VMT\ Reduced\ (\boldsymbol{VR}) = \frac{\mathbf{.14} * \boldsymbol{W} * \boldsymbol{P}}{\mathbf{1.2}} * \mathbf{12.6}$$

where: **.14** = 1999-2003 average percent of total commute trips by carpooling (Table 16a, RPTA, 2003)
W = daily home-based work person trips = 1.6 * total employment in Maricopa County for CMAQ funding request year (MAG trip attraction equation)
P = percent of carpooling attributable to the Regional Rideshare Program
1.2 = average vehicle occupancy for all modes (derived from Table 15, RPTA, 2001)
12.6 = 1999-2001 average commute trip length by all modes (Table 52, RPTA, 2001)

$$Daily\ Emissions\ Reduction = \boldsymbol{VR} * [\frac{w1 * LEF_{CO}}{4} + \frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} + w4 * (LEF_{PM} + PEF)] * \frac{1}{1000} * \frac{250}{365} = \frac{kilograms}{day}$$

where: ***LEF*** = the light duty vehicle emission factor for each pollutant
PEF = the paved road PM-10 emission factor for all road types
w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively
250/365 = factor to convert from an average weekday to an annual average day

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent
life = program period of 1 year

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

RPTA requests $594,000 in FY 2010 CMAQ funds for the Regional Rideshare Program and indicates that the Regional Rideshare Program is responsible for ten percent of employee participation in carpooling. Based on interim projections accepted by the MAG Regional Council in June 2003, the total employment for Maricopa County in 2010 is expected to be 2,112,000.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $594,000.
- *P* = 10%.

Calculations:

$$VMT\ Reduced\ (\boldsymbol{VR}) = \frac{0.14 * (1.6 * 2{,}112{,}000) * 0.10}{1.2} * 12.6 = 496{,}742$$

$$Daily\ Emissions\ Reduction =$$

$$496{,}742 * \left(\frac{0.00 * 8.51}{4} + \frac{0.37 * 0.73}{2} + \frac{0.44 * 0.54}{2} + (1.0 * (0.03 + 0.79))\right) * \frac{1}{1000} * \frac{250}{365} = 365.36\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1 + 0.03)^1 * (0.03)}{(1 + 0.03)^1 - 1} = 1.03$$

$$Cost-Effectiveness = \frac{1.03 * 594{,}000 * 1000}{365.36 * 365} = 4{,}588\ \frac{dollars}{metric\ ton}$$

TELEWORK PROGRAM

"Encouragement of Telecommuting, Teleworking and Teleconferencing" is a committed control measure in the MAG 1999 Serious Area CO and PM-10 Plans. The program encourages employers to set up and institutionalize telecommuting options for employees. The program provides consulting services to implement or expand corporate telecommuting programs, including advice on information technology and telecommunications connectivity. The current outreach effort targets CEOs of companies to obtain top-level commitment. The program also aims to increase general public awareness of telecommuting via TV programs, press releases, and advertisements in corporate publications. The Telework Program reduces emissions by decreasing the total vehicle miles of travel (VMT) for commute trips.

Based on averages for 1999-2003 from TDM surveys conducted by RPTA, 3.5 percent of daily commute trips are replaced by telecommuting (RPTA, 2003). The average trip length of commute trips by telecommuters is 19.0 miles (RPTA, 2000a). The MOBILE6 model will be run for the CMAQ funding year to estimate average light duty vehicle emissions of CO, TOG, NOx, and PM-10 (**LEF_{CO}, LEF_{TOG}, LEF_{NOx},** and **LEF_{PM}**) in grams per mile. The emission factors will be multiplied by the reduction in vehicle miles of travel (**VR**) to estimate the emissions benefit of the Telework Program.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Percent of telecommuting attributable to the Telework Program (***P***).

Formulas:

$$Commute\ Trips\ Avoided\ (\boldsymbol{CTA}) = \frac{\mathbf{.035} * \boldsymbol{W}}{\mathbf{1.2}}$$

$$VMT\ Reduced\ (\boldsymbol{VR}) = \boldsymbol{CTA} * \boldsymbol{P} * \mathbf{19.0}$$

where: **.035** = 1999-2003 average percent of commute trips replaced by telecommuting on an average weekday (Table 16a, RPTA, 2003)
W= daily home-based work person trips = 1.6 * total employment in Maricopa County in the CMAQ funding request year (from MAG trip generation equation)
1.2 = average vehicle occupancy (derived from Table 15, RPTA, 2001)
P = percent of telecommuting attributable to the Telework Program
19.0 = average one-way commute trip length in miles for telecommuters (Table 4, RPTA, 2000a)

$$Daily\ Emissions\ Reduction = \boldsymbol{VR} * \left[\frac{w1 * LEF_{CO}}{4} + \frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} + w4 * (LEF_{PM} + PEF)\right] * \frac{1}{1000} * \frac{250}{365} = \frac{kilograms}{day}$$

where: ***LEF*** = the light duty vehicle emission factor for each pollutant
PEF = the paved road PM-10 emission factor for all road types
w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively
250/365 = factor to convert from an average weekday to an annual average day

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{\boldsymbol{life}}\ (i)}{(1+i)^{\boldsymbol{life}} - 1}$$

where: ***i*** = discount rate of 3 percent
life = program period of 1 year

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Telework Program EXAMPLE

RPTA requests $300,000 in FY 2010 CMAQ funds for the Telework Program. RPTA indicates that the share of telecommuting attributable to the Telework Program is 20 percent. Based on interim projections accepted by the MAG Regional Council in June 2003, the total employment for Maricopa County in 2010 is expected to be 2,112,000.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $300,000.
- ***P*** = 20%.

Calculations:

$$Commute\ Trips\ Avoided\ (\boldsymbol{CTA}) = \frac{.035 * (1.6 * 2{,}112{,}000)}{1.2} = 98{,}560$$

$$VMT\ Reduced\ (\boldsymbol{VR}) = 98{,}560 * .20 * 19.0 = 374{,}528$$

$$Daily\ Emissions\ Reduction =$$

$$374{,}528 * (\frac{0.00 * 8.51}{4} + \frac{0.37 * 0.73}{2} + \frac{0.44 * 0.54}{2} + (1.0 * (0.03 + 0.79))) * \frac{1}{1000} * \frac{250}{365} = 275.47\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1 + 0.03)^1 * (0.03)}{(1 + 0.03)^1 - 1} = 1.03$$

$$Cost-Effectiveness = \frac{1.03 * 300{,}000 * 1000}{275.47 * 365} = 3{,}073\ \frac{dollars}{metric\ ton}$$

TRAFFIC FLOW IMPROVEMENTS

"Coordinate Traffic Signal Systems," "Develop Intelligent Transportation Systems," and "Reduce Traffic Congestion at Major Intersections" are committed control measures in the MAG 1999 Serious Area CO and PM-10 Plans and the CO and one-hour ozone maintenance plans. These measures reduce CO, TOG, and NOx emissions by increasing vehicle speeds and reducing congestion. These measures do not affect PM-10, because PM-10 emissions are not sensitive to changes in vehicle speeds.

Traffic Signal Coordination and Freeway Management System (FMS) projects belong to a class of projects called Intelligent Transportation Systems (ITS). The Federal Highway Administration has developed software called the ITS Deployment Analysis System (IDAS) to use in planning for ITS projects (http://idas.camsys.com/). IDAS estimates benefits and costs for more than 60 types of ITS projects. In addition to other measures of performance, IDAS estimates emission benefits resulting from implementation of ITS projects. MAG will run the IDAS model to estimate the CO, TOG, and NOx emission reductions for traffic signal coordination, FMS, and other ITS projects that are CMAQ-funded. IDAS emissions will be weighted and summed to calculate the cost-effectiveness of traffic signal coordination projects, as described below.

Traffic Signal Coordination

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Length of project (***miles***).
- Current average weekday traffic (***ADT***).

Formulas:

$$\textit{Daily Emissions Reduction} = \left(\frac{w1 * IER_{CO}}{4} + \frac{w2 * IER_{TOG}}{2} + \frac{w3 * IER_{NOx}}{2}\right) = \frac{kilograms}{day}$$

where: ***IER***= the IDAS-estimated emissions reduction for each pollutant in kilograms/day
w1-w3 = weighting factors for CO, TOG, and NOx, respectively

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 5 years (CARB, 2005)

$$Cost\text{-}Effectiveness = \frac{\mathbf{CRF} * \mathbf{CMAQ\ Cost} * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Traffic Signal Coordination EXAMPLE

A city proposes to install a system in FY 2009 that synchronizes the traffic lights on three miles of street. The city will be replacing non-interconnected signals having traffic-actuated controllers with an advanced computer-based control system. The cost of the system is $475,000. The city proposes to pay $50,000 and requests $425,000 of CMAQ funding. The weekday traffic on the road is estimated to be 10,000 vehicles per day.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $425,000.
- Length of project (***miles***) = 3.
- Average weekday traffic (***ADT***) = 10,000.

Calculations:

$$Daily\ Emissions\ Reduction = \left(\frac{0.00 * 13.92}{4} + \frac{.37 * 2.46}{2} + \frac{.44 * 2.46}{2}\right) = 1.00\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\mathbf{CRF}) = \frac{(1 + 0.03)^5 * (0.03)}{(1 + 0.03)^5 - 1} = 0.2184$$

$$Cost\text{-}Effectiveness = \frac{0.2184 * 425{,}000 * 1000}{1.00 * 365} = 254{,}301\ \frac{dollars}{metric\ ton}$$

Intelligent Transportation Systems

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Length of project (***miles***).

Formulas:

$$Daily\ Emissions\ Reduction = \left(\frac{w1 * IER_{CO}}{4} + \frac{w2 * IER_{TOG}}{2} + \frac{w3 * IER_{NOx}}{2}\right) = \frac{kilograms}{day}$$

where: ***IER***= the IDAS-estimated emissions reduction for each pollutant in kilograms/day
w1-w3 = weighting factors for CO, TOG, and NOx, respectively

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 10 years (CARB, 2005)

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ\ Cost} * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Intelligent Transportation Systems EXAMPLE

A city proposes to install ITS on three miles of road in FY 2009. The cost of the project is $600,000. The city proposes to pay $60,000 and is requesting $540,000 in CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Funding*** = $540,000.
- Length of project (***miles***) = 3.

Calculations:

$$Daily\ Emissions\ Reduction = (\frac{0.00 * 13.92}{4} + \frac{.37 * 2.46}{2} + \frac{.44 * 2.46}{2}) = 1.00\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1 + 0.03)^{10} * (0.03)}{(1 + 0.03)^{10} - 1} = 0.1172$$

$$Cost-Effectiveness = \frac{0.1172 * 540{,}000 * 1000}{1.00 * 365} = 173{,}392\ \frac{dollars}{metric\ ton}$$

<u>Freeway Management System</u>

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.
- Length of project (***miles***).

Formulas:

$$Daily\ Emissions\ Reduction = (\frac{w1 * IER_{CO}}{4} + \frac{w2 * IER_{TOG}}{2} + \frac{w3 * IER_{NOx}}{2}) = \frac{kilograms}{day}$$

where: ***IER***= the IDAS-estimated emissions reduction for each pollutant in kilograms/day
w1-w3 = weighting factors for CO, TOG, and NOx, respectively

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1 + i)^{\boldsymbol{life}}\ (i)}{(1 + i)^{\boldsymbol{life}} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 10 years

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

ADOT proposes to add an additional three miles of freeway to the freeway management system in FY 2009. The cost of the project is $3,345,000. ADOT proposes to pay $334,500 and requests $3,010,500 in CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $3,010,500.
- Length of project (***miles***) = 3.

Calculations:

$$\textit{Daily Emissions Reduction} = \left(\frac{0.00 * 13.92}{4} + \frac{.37 * 2.46}{2} + \frac{.44 * 2.46}{2}\right) = 1.00\ \frac{\textit{kilograms}}{\textit{day}}$$

$$\textit{Capital Recovery Factor } (\textbf{\textit{CRF}}) = \frac{(1 + 0.03)^{10} * (0.03)}{(1 + 0.03)^{10} - 1} = 0.1172$$

$$\textit{Cost-Effectiveness} = \frac{0.1172 * 3{,}010{,}500 * 1000}{1.00 * 365} = 969{,}870\ \frac{\textit{dollars}}{\textit{metric ton}}$$

TRIP REDUCTION PROGRAM

"Trip Reduction Program" is a committed control measure in the MAG 1999 Serious Area CO and PM-10 Plans. The Trip Reduction Program requires employers with 50 or more employees at a work site in Area A to achieve target reductions in single occupant vehicle (SOV) trips through use of alternate transportation modes. Alternate transportation modes include carpooling, vanpooling, taking the bus, bicycling, and walking. Reductions in SOV trips due to telecommuting or compressed work schedules also qualify for credit in the trip reduction program. The program reduces emissions by decreasing the total vehicle miles of travel (VMT) for commute trips.

The Maricopa County Trip Reduction Program (TRP) maintains detailed information on participating organizations and their employees. For the period 1998-2002, the TRP indicates that 33 percent of employees work for TRP organizations and 26 percent of the commute trips taken by these employees are by alternate modes (or the commute trip is eliminated, in the case of telecommuting and compressed work weeks). In addition, the average one-way commute trip length for TRP employees is 11.4 miles and the average vehicle occupancy for TRP commute trips is 1.16.

The MOBILE6 model will be run for the CMAQ funding year to estimate the average light duty vehicle emissions of CO, TOG, NOx, and PM-10 (LEF_{CO}, LEF_{TOG}, LEF_{NOx}, *and* LEF_{PM}) in grams per mile. The emission factors will be multiplied by the reduction in vehicle miles of travel (***VR***) to estimate the emissions benefit of the Trip Reduction Program.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost.***
- Percent of alternate mode use attributable to the Trip Reduction Program (***P***).

Formulas:

$$VMT\ Reduced\ (\boldsymbol{VR}) = \frac{\mathbf{.26} * \boldsymbol{W} * \mathbf{.33} * \boldsymbol{P}}{\mathbf{1.16}} * \mathbf{11.4}$$

where: **.26** = the percent of work trips in TRP organizations using alternate modes, including telecommuting and compressed work schedules (from 1998-2002 TRP data)
W = daily home-based work person trips = 1.6 * total employment in Area A in the CMAQ funding request year (from MAG trip generation equation)
.33 = percent of employees working for a TRP organization with at least 50 employees (from 1998-2002 TRP data)
P = percent of alternate mode use attributable to the Trip Reduction Program
1.16 = average vehicle occupancy (from 1998-2002 TRP data)
11.4 = average one-way commute trip length (from 1998-2002 TRP data)

$$Daily\ Emissions\ Reduction =$$

$$\boldsymbol{VR} * \left[\frac{w1 * LEF_{CO}}{4} + \frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} + w4 * (LEF_{PM} + PEF)\right] * \frac{1}{1000} * \frac{250}{365} = \frac{kilograms}{day}$$

where: ***LEF*** = the light duty vehicle emission factor for each pollutant
PEF = the paved road PM-10 emission factor for all road types
w1-w4 = weighting factors for CO, TOG, NOx, and PM-10, respectively
250/365 = factor to convert from an average weekday to an annual average day

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{life}\ (i)}{(1+i)^{life} - 1}$$

where: ***i*** = discount rate of 3 percent
life = program period of 1 year

$$Cost\text{-}Effectiveness = \frac{\textbf{CRF} * \textbf{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Trip Reduction Program **EXAMPLE**

Maricopa County requests $910,000 in FY 2010 CMAQ funds for the Trip Reduction Program. The Arizona Department of Environmental Quality contributes $948,000 to the program. The County indicates that the share of alternative mode use attributable to the Trip Reduction Program is 25 percent. Based on interim projections accepted by the MAG Regional Council in June 2003, the total employment for Maricopa County in 2010 is expected to be 2,112,000. Area A includes the most populous areas of Maricopa County, as well as the Apache Junction and Queen Creek areas of Pinal County. In 2010 it is estimated that there will be approximately 2.2 million people working in Area A.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $910,000.
- ***P*** = 25%.

Calculations:

$$VMT\ Reduced\ (\textbf{VR}) = \frac{.26 * (1.6 * 2{,}200{,}000) * .33 * .25}{1.16} * 11.4 = 742{,}022$$

$$Daily\ Emissions\ Reduction =$$

$$742{,}022 * \left(\frac{0.00 * 8.51}{4} + \frac{0.37 * 0.73}{2} + \frac{0.44 * 0.54}{2} + (1.0 * (0.03 + 0.79))\right) * \frac{1}{1000} * \frac{250}{365} = 545.77\ \frac{kilograms}{day}$$

$$Capital\ Recovery\ Factor\ (\textbf{CRF}) = \frac{(1 + 0.03)^1 * (0.03)}{(1 + 0.03)^1 - 1} = 1.03$$

$$Cost\text{-}Effectiveness = \frac{1.03 * 910{,}000 * 1000}{545.77 * 365} = 4{,}705\ \frac{dollars}{metric\ ton}$$

VANPOOL VEHICLES

"Encouragement of Vanpooling" is a committed control measure in the MAG 1999 Serious Area CO and PM-10 Plans. Vanpools reduce emissions by decreasing the total vehicle miles of travel (VMT) for commute trips.

Valley Metro indicates that a vanpool vehicle travels 66 miles (on average - round trip) per day on 255 commute days per year. This is equal to 16,830 commute miles annually per van. Valley Metro estimates that the average vanpool carries nine people, including the driver. It will be assumed that each vanpool passenger drives an average of three miles round trip to access the vanpool, which reduces the daily commute miles saved to 63 per passenger. This reduction accounts for vanpool passengers driving (park-and-ride) or being dropped off (kiss-and-ride) or the vanpool driver picking up and dropping off passengers. It will also be assumed that the average vehicle occupancy for commute trips by all modes is 1.2 (RPTA, 2001). Based on these assumptions, 16,830 miles per van (vanpool miles) will replace 121,125 commute miles per year. Therefore, each vanpool reduces automobile VMT by 104,295 miles annually and each vanpool mile replaces approximately 7.2 commute miles.

The MOBILE6 model will be run for the year that the CMAQ funds are requested to estimate the average light duty vehicle emissions of CO, TOG, NOx, and PM-10 ($\boldsymbol{LEF_{CO}}$, $\boldsymbol{LEF_{TOG}}$, $\boldsymbol{LEF_{NOx}}$, and $\boldsymbol{LEF_{PM}}$) in grams per mile. The equivalent emission factors for light-duty gas trucks, LDGT34, ($\boldsymbol{VEF_{CO}}$, $\boldsymbol{VEF_{TOG}}$, $\boldsymbol{VEF_{NOx}}$, and $\boldsymbol{VEF_{PM}}$), which includes full size vans, will also be estimated using MOBILE6. The emission factors will be multiplied by the appropriate vehicle miles of travel to estimate commute and vanpool emissions. The difference between the commute and vanpool emissions represents the net emission reduction benefit of vanpools.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost***.

Formulas:

$$\textit{Emissions Reduced } (\boldsymbol{ER}) = \boldsymbol{miles_{commute}} * \left(\frac{w1 * LEF_{CO}}{4} + \frac{w2 * LEF_{TOG}}{2} + \frac{w3 * LEF_{NOx}}{2} + w4 * (LEF_{PM} + PEF)\right) * \frac{1}{1000}$$

where: $\boldsymbol{miles_{commute}}$ = the commute miles replaced by the vanpool each year
$\boldsymbol{LEF}$ = the light duty vehicle emission factor for each pollutant
$\boldsymbol{PEF}$ = the paved road PM-10 emission factor for all road types

$$Vanpool\ Emissions\ (\boldsymbol{VE}) = \boldsymbol{miles_{vanpool}} * \left(\frac{w1 * VEF_{CO}}{4} + \frac{w2 * VEF_{TOG}}{2} + \frac{w3 * VEF_{NOx}}{2} + w4 * VEF_{PM}\right) * \frac{1}{1000}$$

where: $\boldsymbol{miles_{vanpool}}$ = the miles driven annually by a van used for a vanpool
VEF = the emission factors for a van (LDGT34) for each pollutant

$$Daily\ Emissions\ Reduction = (\boldsymbol{ER} - \boldsymbol{VE}) * \frac{1}{365} = \frac{kilograms}{day}$$

where: **1/365** = factor to convert annual emissions to daily emissions

$$Capital\ Recovery\ Factor\ (\boldsymbol{CRF}) = \frac{(1+i)^{\boldsymbol{life}}\ (i)}{(1+i)^{\boldsymbol{life}} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 4 years

$$Cost-Effectiveness = \frac{\boldsymbol{CRF} * \boldsymbol{CMAQ}\ Cost * 1000}{Daily\ Emissions\ Reduction * 365} = \frac{dollars}{metric\ ton}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

Vanpool Vehicles EXAMPLE

RPTA proposes to purchase a fifteen-passenger van to be used in a vanpool. The cost of the van is $25,000. RPTA requests $25,000 of FY 2005 CMAQ funding.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $25,000.

Calculations:

$$\textit{Emissions Reduced } (\boldsymbol{ER}) = 121{,}125 * \left(\frac{0.00 * 10.92}{4} + \frac{0.37 * 1.11}{2} + \frac{0.44 * 0.92}{2} + (1.0 * (0.03 + 0.79))\right) * \frac{1}{1000} = 149.71 \ \frac{\textit{kilograms}}{\textit{year}}$$

$$\textit{Vanpool Emissions } (\boldsymbol{VE}) = 16{,}830 * \left(\frac{0.00 * 12.34}{4} + \frac{0.37 * 1.51}{2} + \frac{0.44 * 1.31}{2} + (1.0 * (0.03 + 0.79))\right) * \frac{1}{1000} = 23.35 \ \frac{\textit{kilograms}}{\textit{year}}$$

$$\textit{Daily Emissions Reduction} = (149.71 - 23.35) * \frac{1}{365} = 0.35 \ \frac{\textit{kilograms}}{\textit{day}}$$

$$\textit{Capital Recovery Factor } (\boldsymbol{CRF}) = \frac{(1 + 0.03)^4 * (0.03)}{(1 + 0.03)^4 - 1} = 0.2690$$

$$\textit{Cost-Effectiveness} = \frac{0.269 * 25{,}000 * 1000}{0.35 * 365} = 52{,}642 \ \frac{\textit{dollars}}{\textit{metric ton}}$$

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